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Ashida et al.

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(54) **BAND-PASS FILTER**

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(73) Assignee: **TDK CORPORATION**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **Nov. 2, 2018**

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(51) **Int. Cl.**
H01P 1/203 (2006.01)
H03H 7/01 (2006.01)

(52) **U.S. Cl.**
CPC ***H01P 1/20345*** (2013.01); ***H01P 1/2039*** (2013.01); ***H01P 1/20309*** (2013.01); ***H01P 1/20381*** (2013.01); ***H03H 7/0115*** (2013.01); ***H03H 7/0161*** (2013.01)

(58) **Field of Classification Search**
CPC H03H 7/0115; H03H 2001/0085; H03H 7/09; H01P 1/20345; H01P 1/20309
USPC 333/175, 185, 177
See application file for complete search history.

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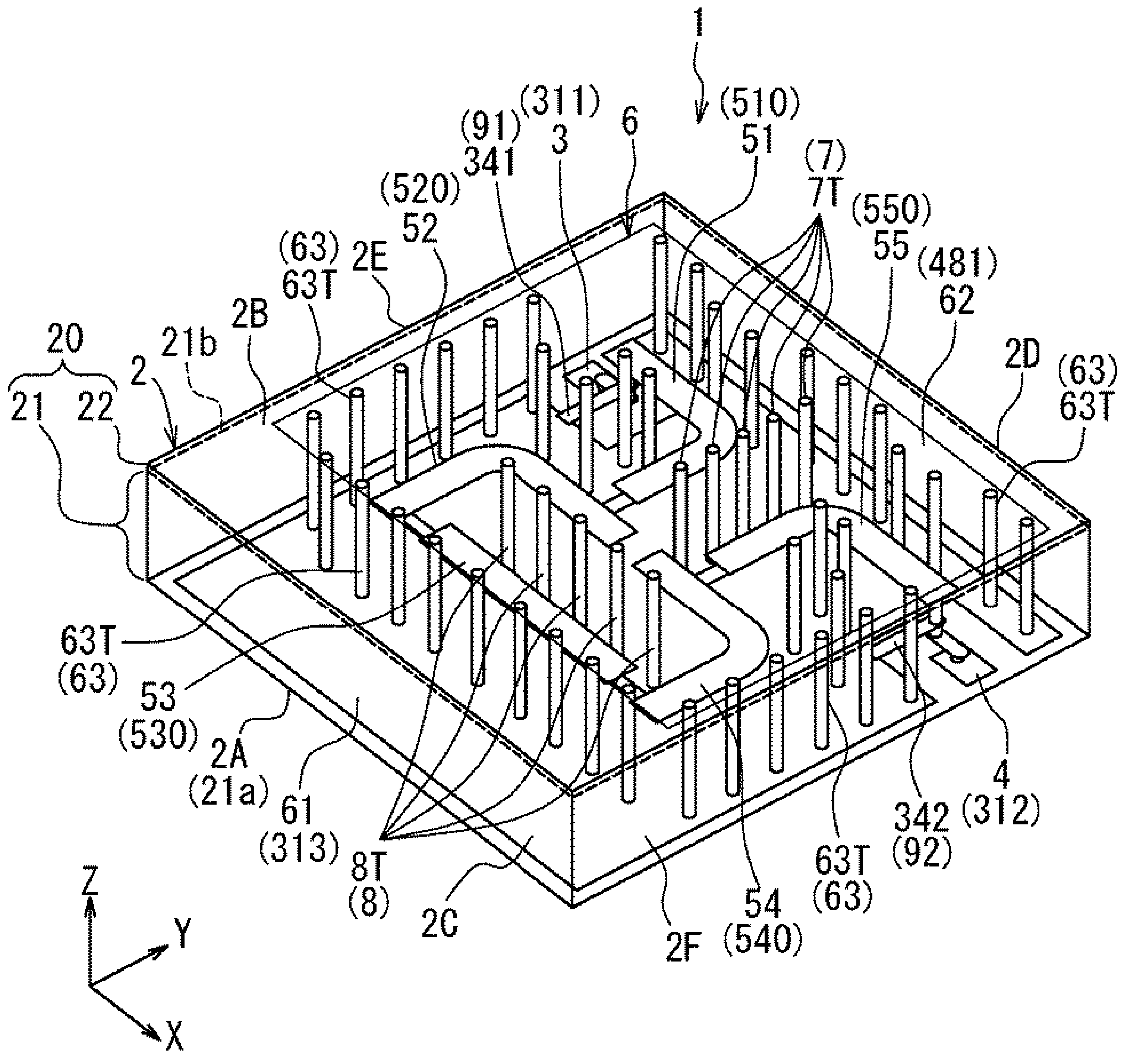
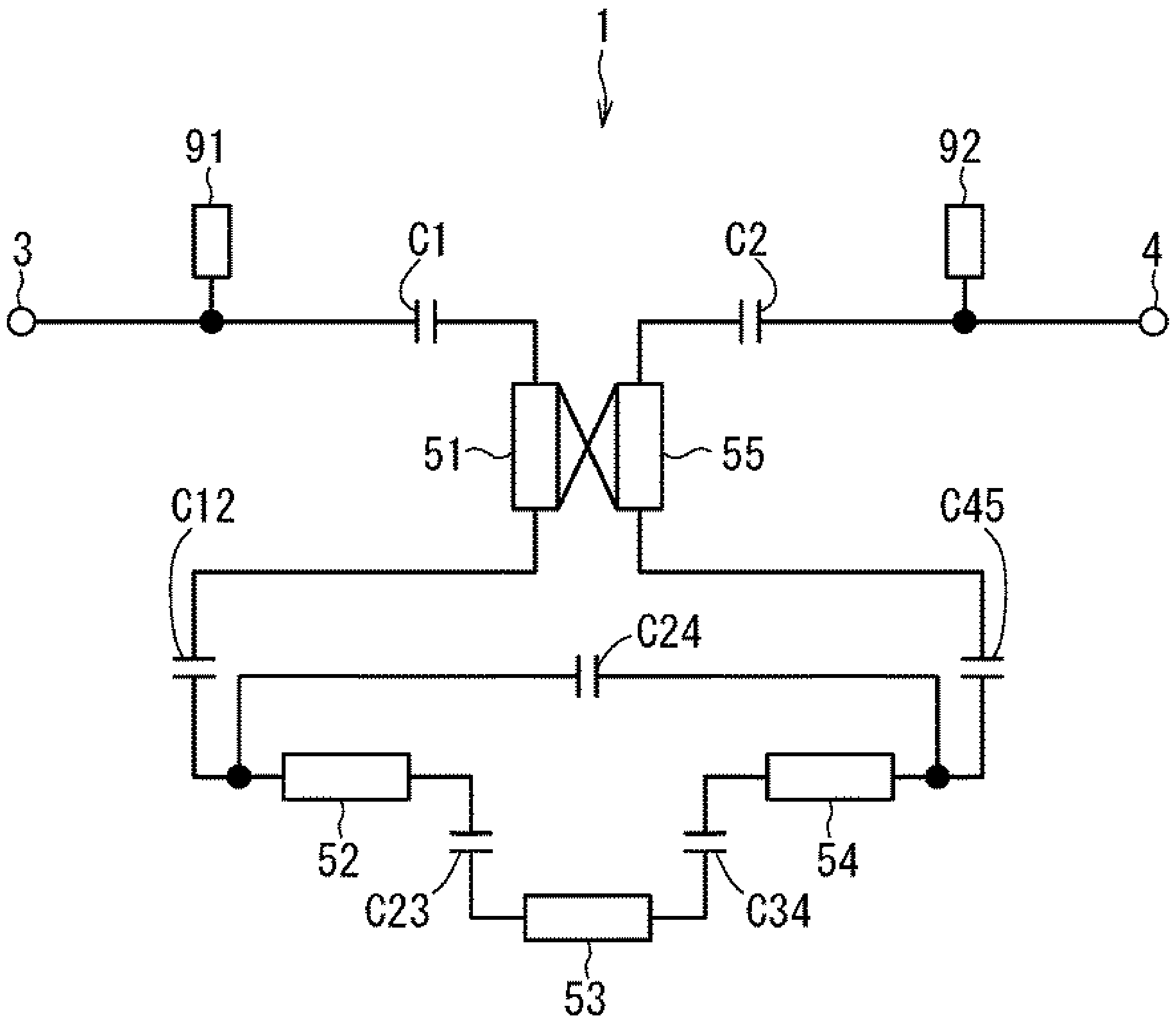
Primary Examiner — Rakesh B Patel
(74) *Attorney, Agent, or Firm* — Oliff PLC

(57) **ABSTRACT**

A band-pass filter includes a main body, five resonators, a shield, and a partition. The main body is formed of a dielectric. The partition is formed of a conductor. The five resonators are configured so that capacitive coupling is established between every two of the resonators adjacent to each other in circuit configuration. Each of the five resonators includes a resonator conductor portion. A first stage resonator and a fifth stage resonator are magnetically coupled to each other although not adjacent to each other in circuit configuration. The partition extends to pass between the respective resonator conductor portions of the first stage resonator and the fifth stage resonator, and is electrically connected to the shield.

20 Claims, 18 Drawing Sheets





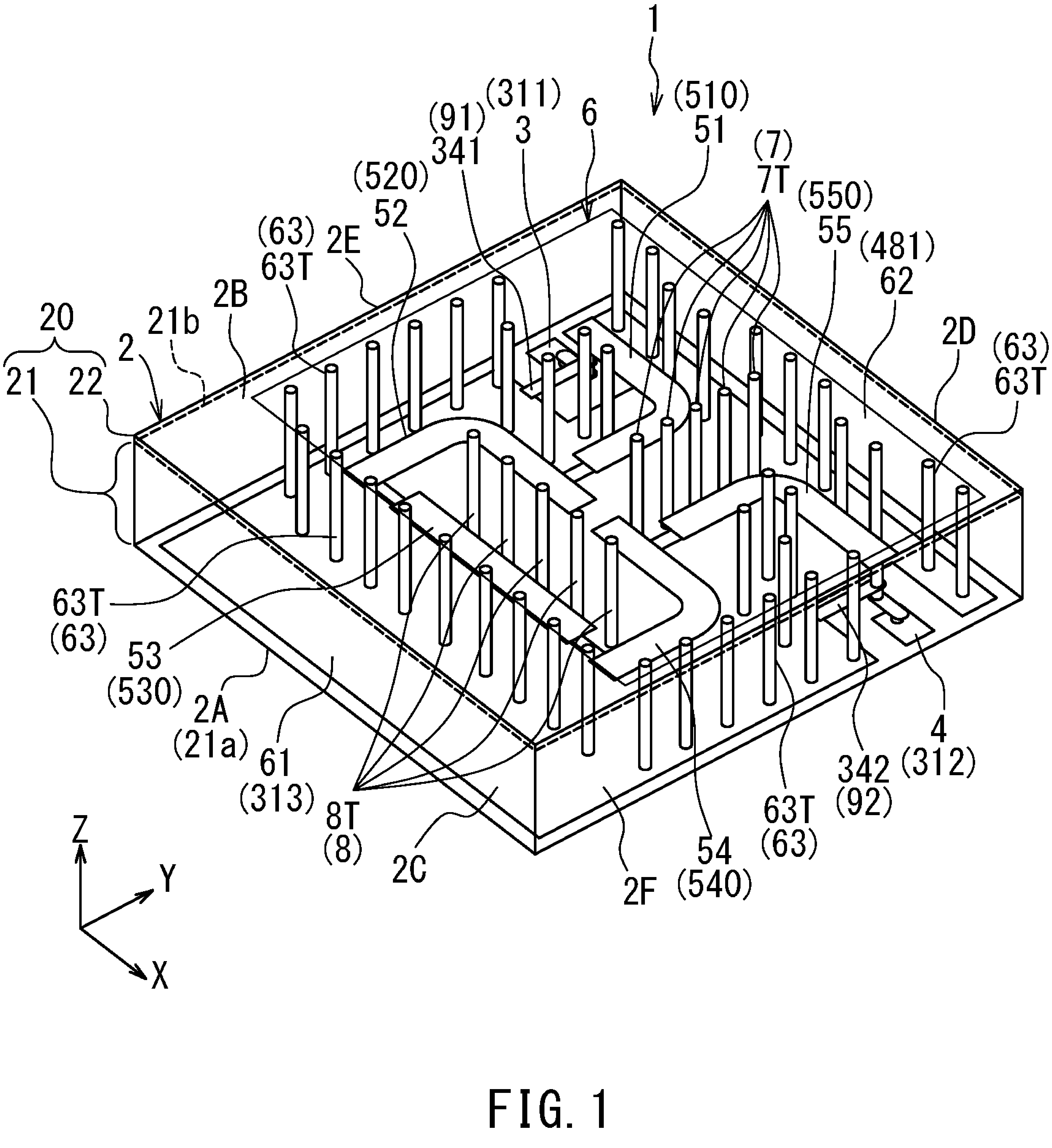

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FIG. 1

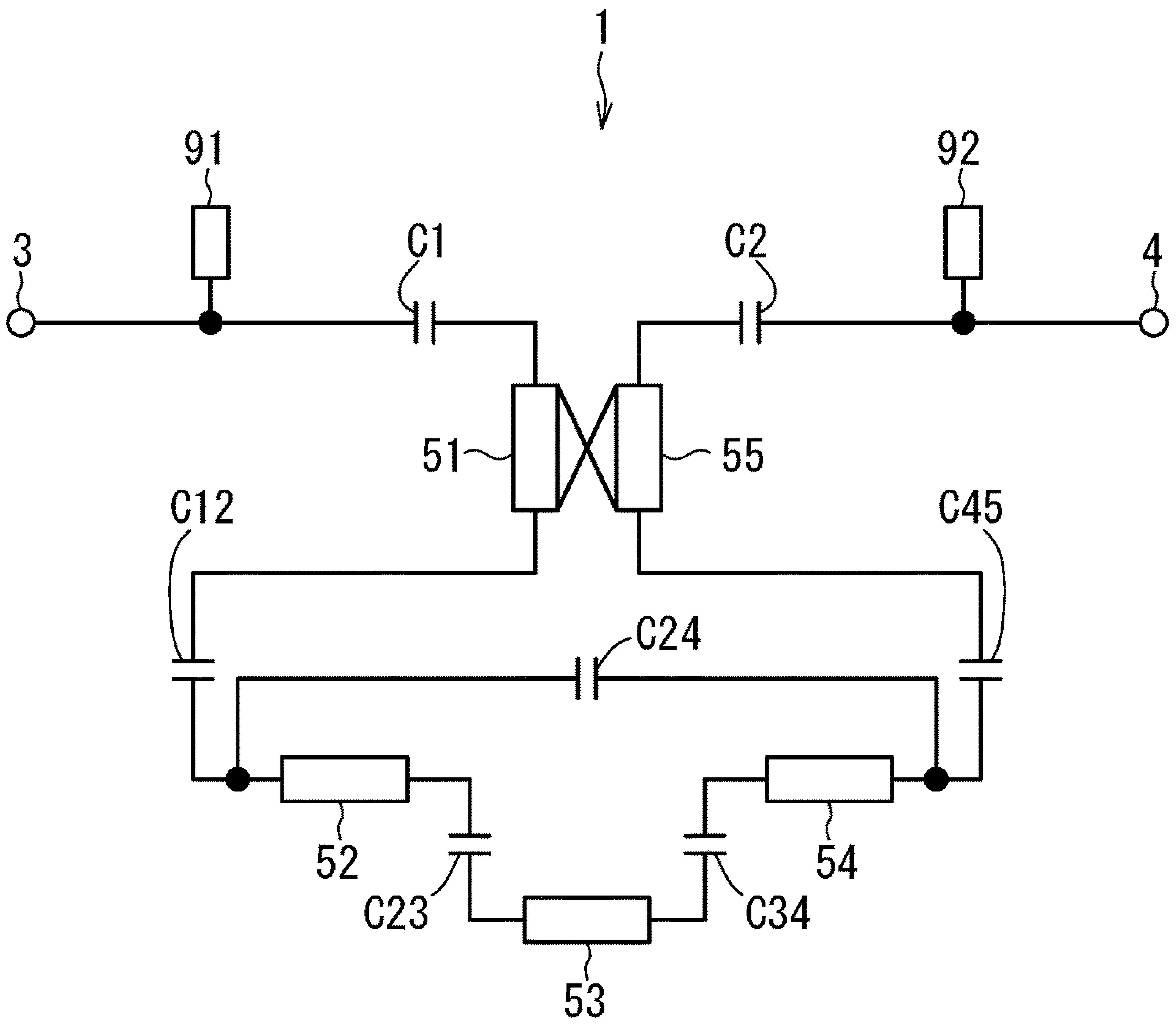
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FIG. 2

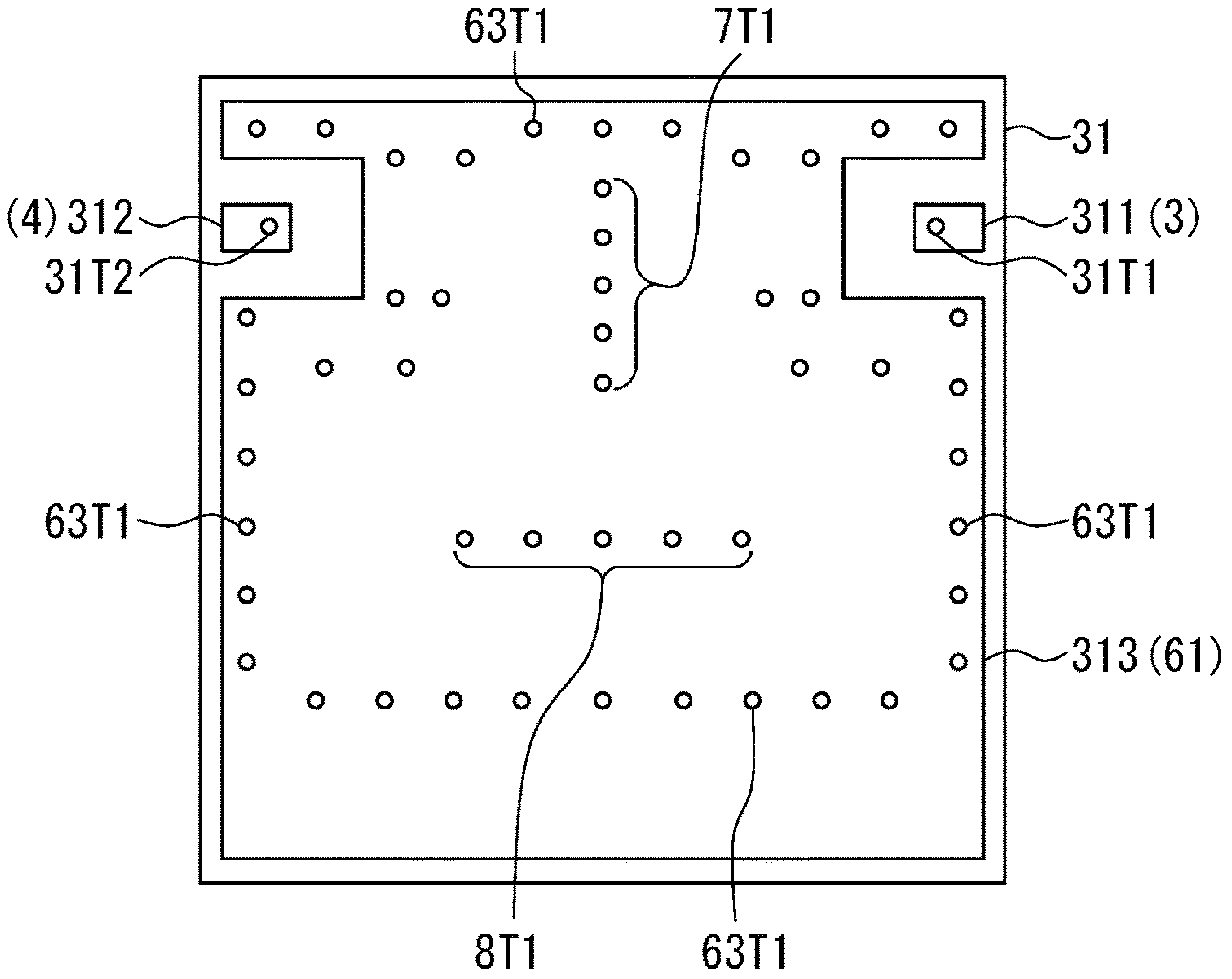
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FIG. 3

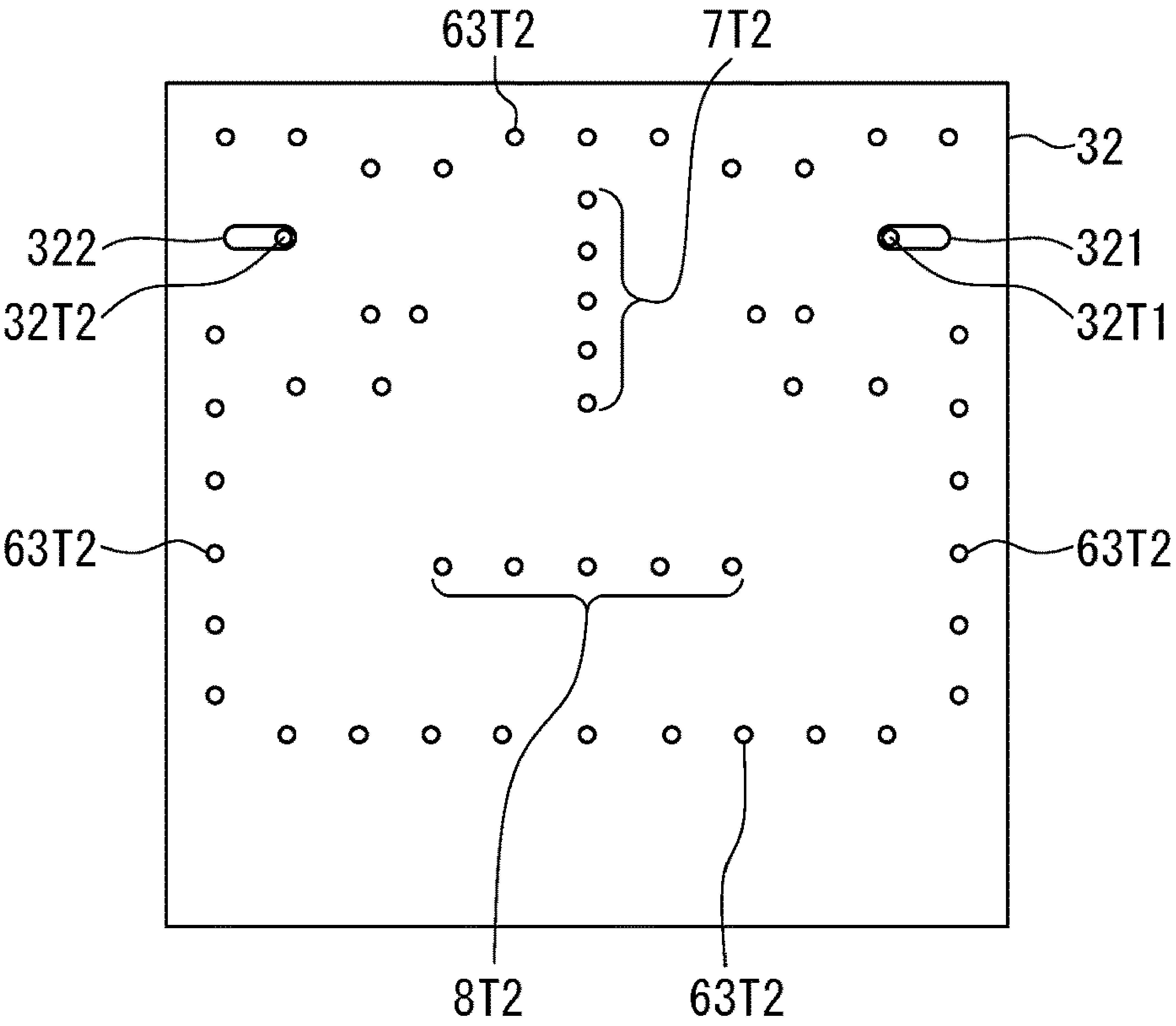
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FIG. 4

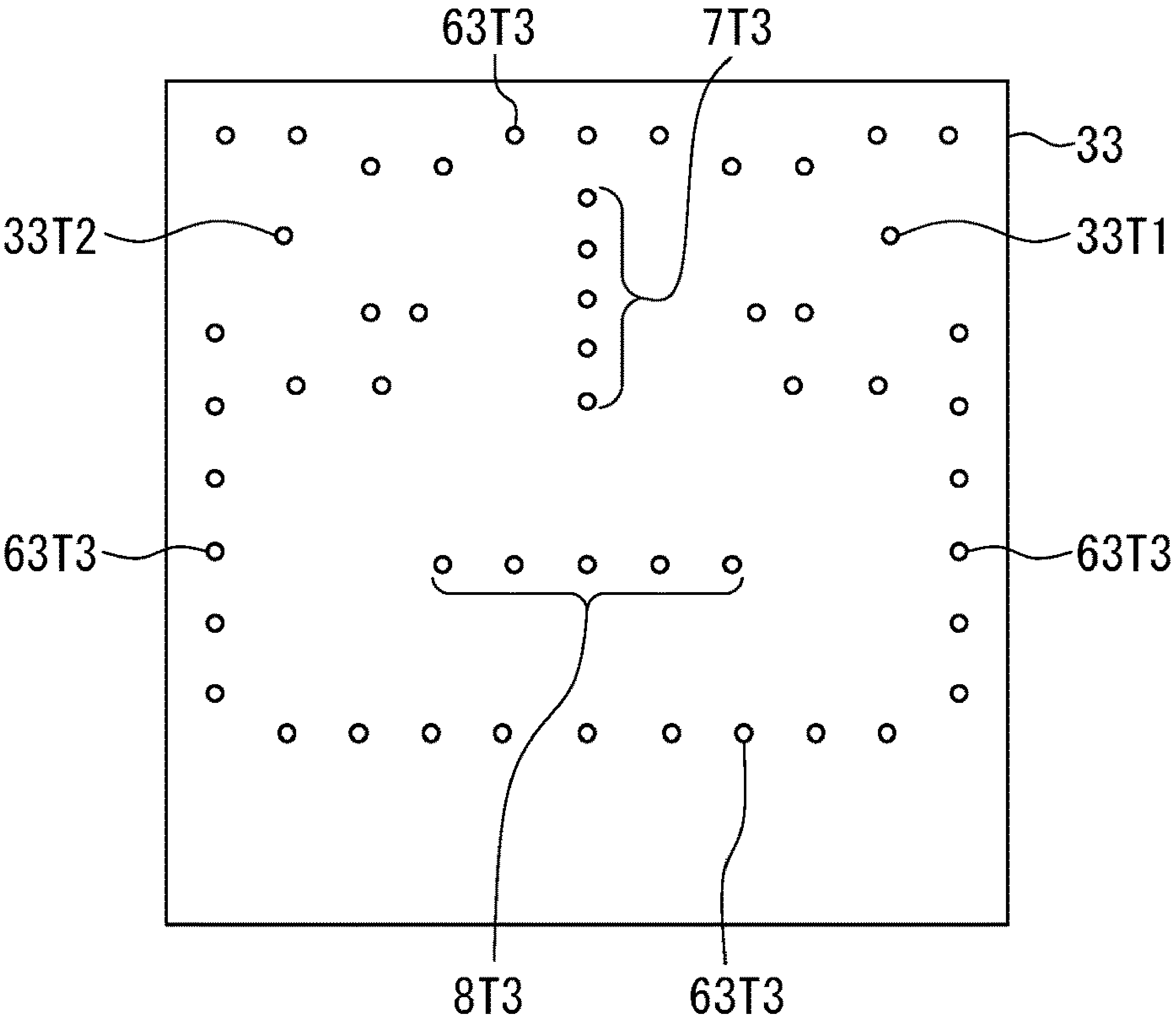
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FIG. 5

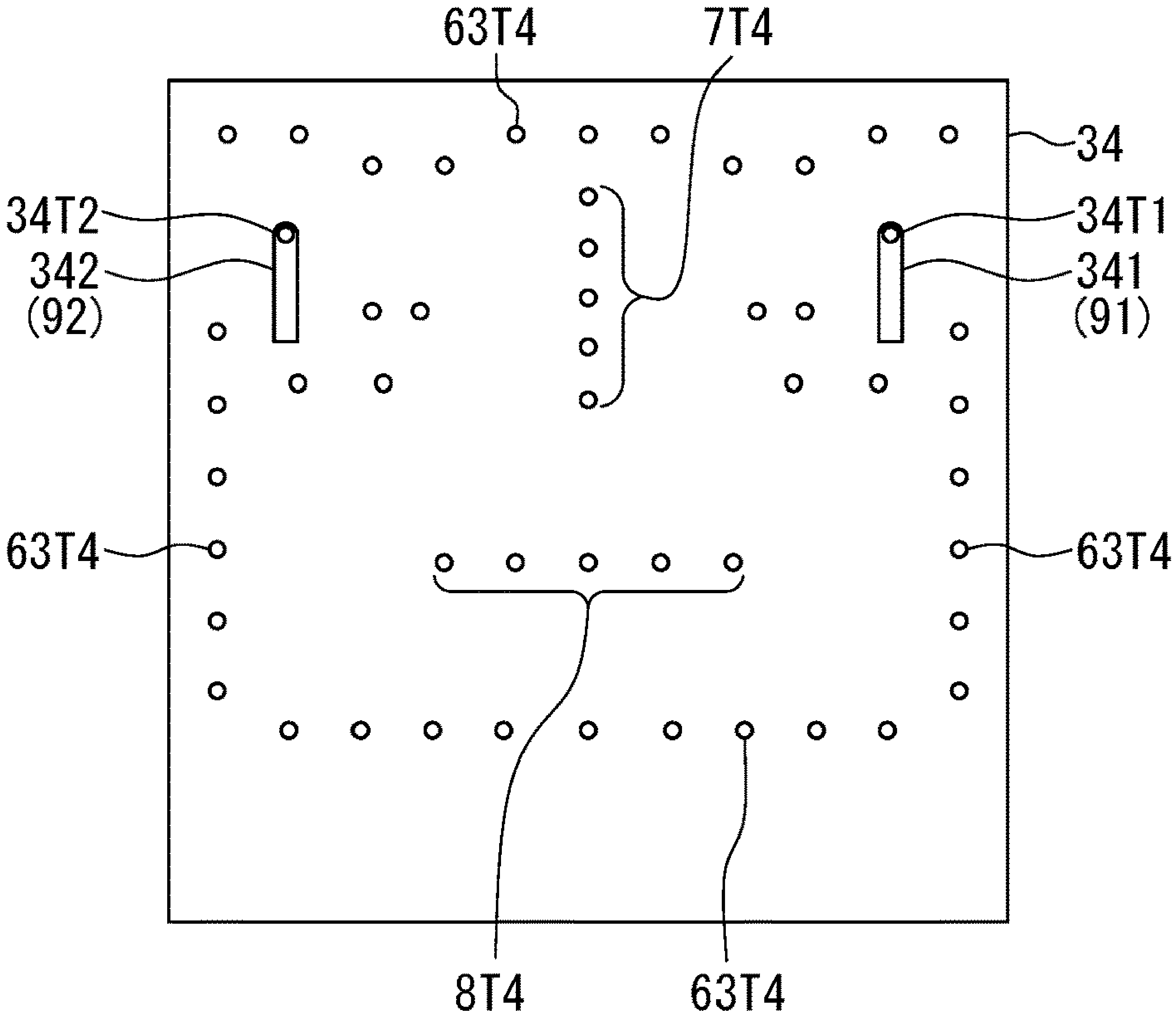
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FIG. 6

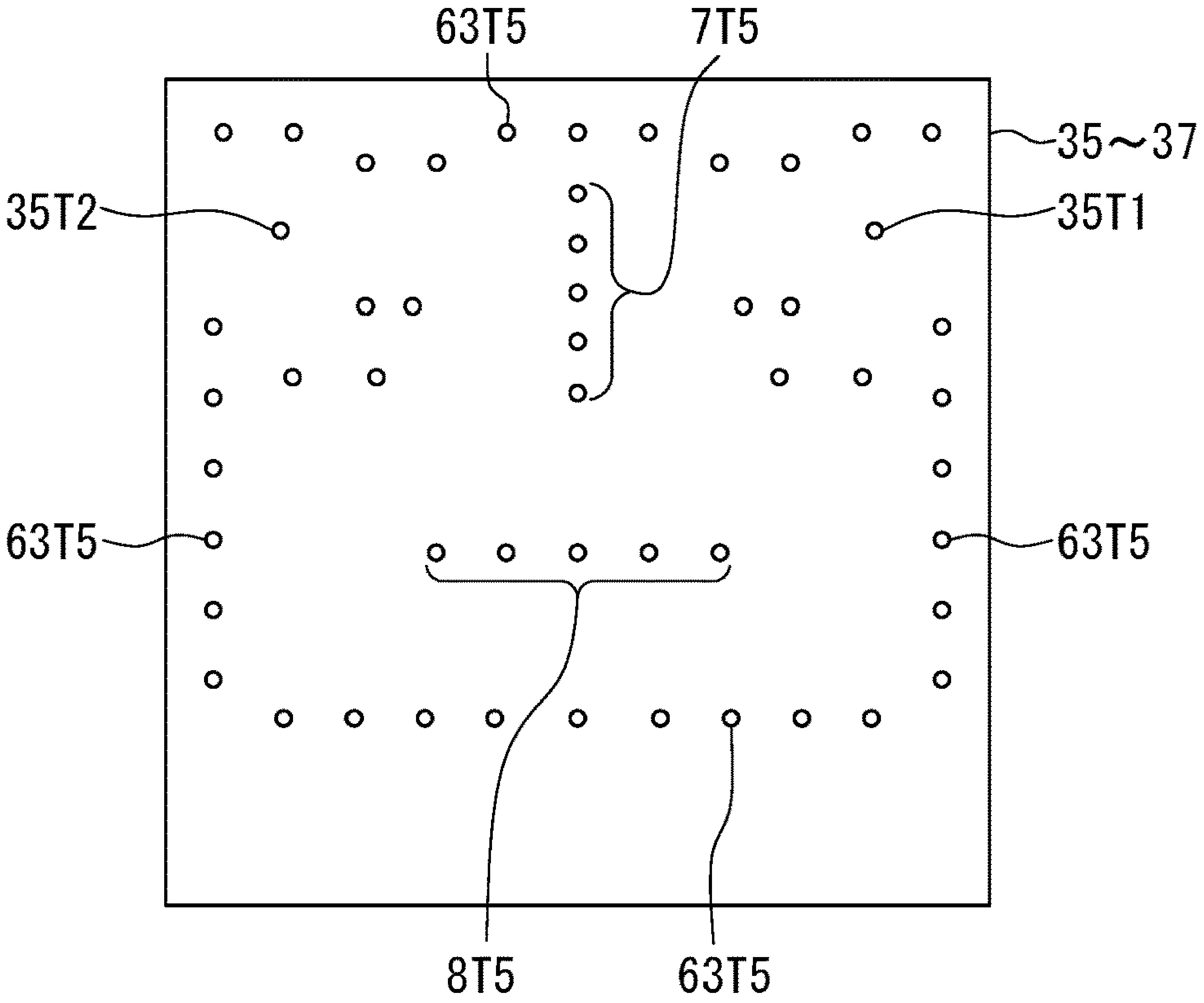
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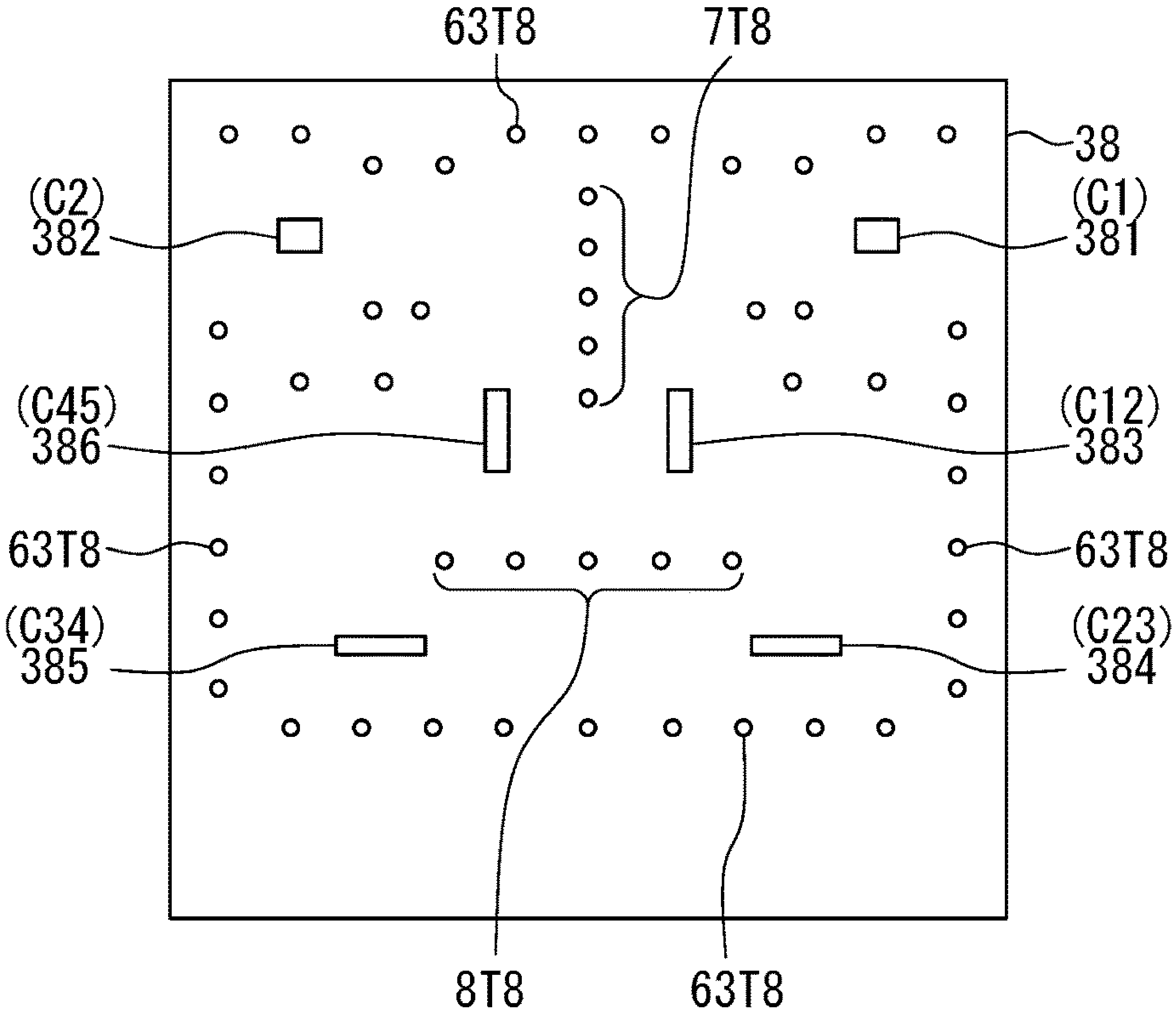
FIG. 7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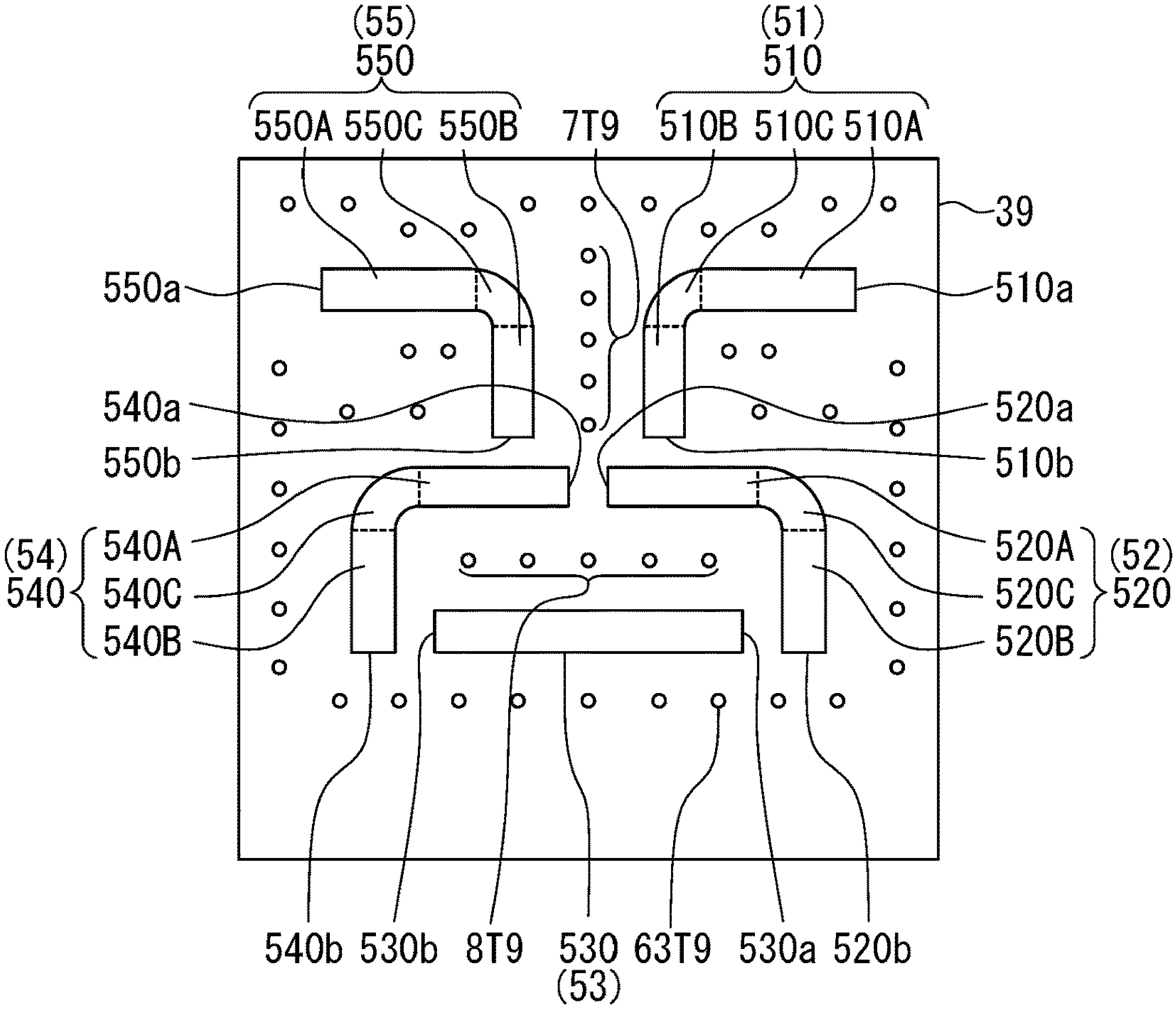
(C34)
385
(C23)
384
8T8
63T8

FIG. 8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550b
510b
540A
520A
(54)
540
540C
520C
(52)
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540B
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540b
530b
8T9
530
(53)
63T9
530a
520b

FIG. 9

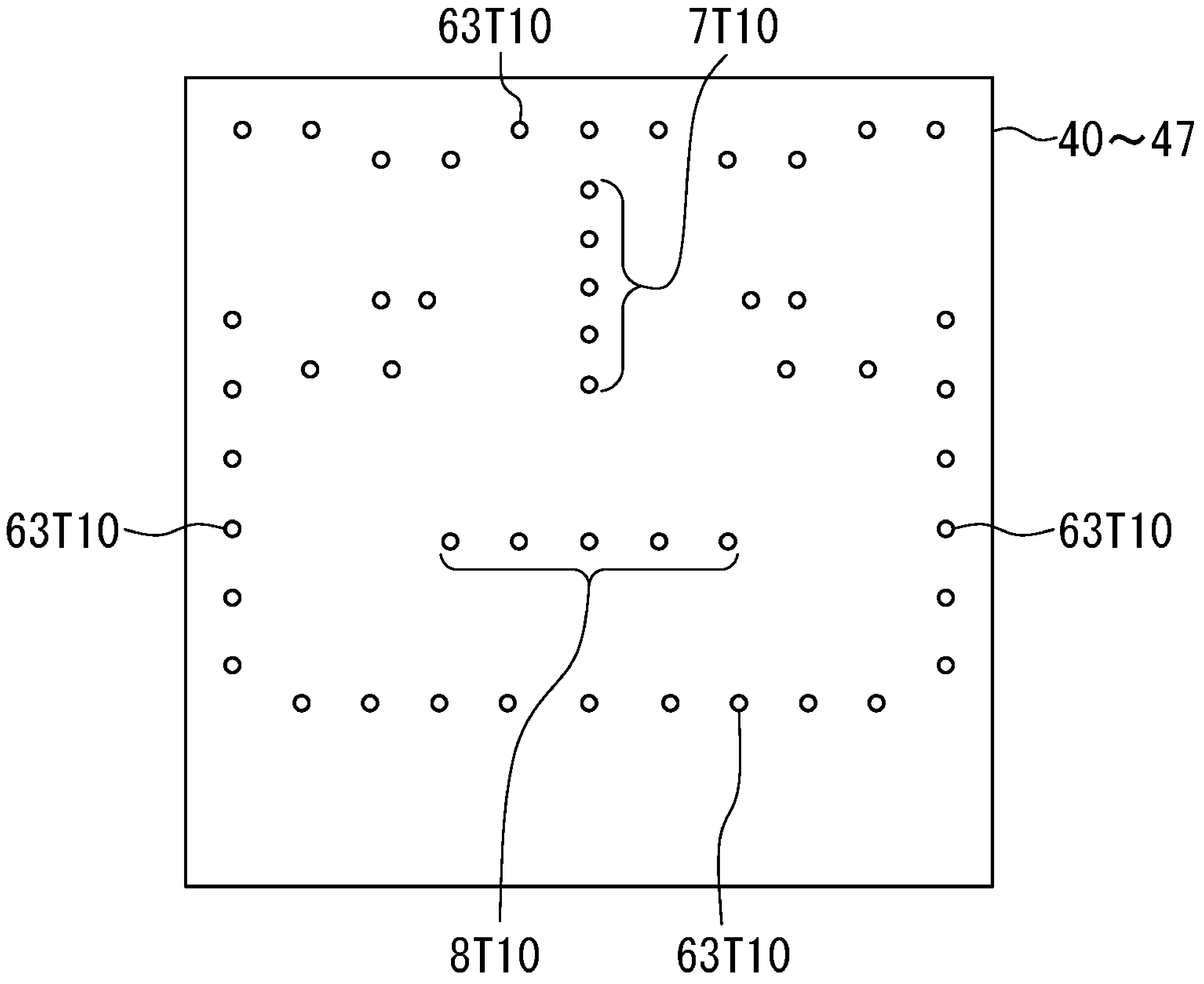


FIG. 10

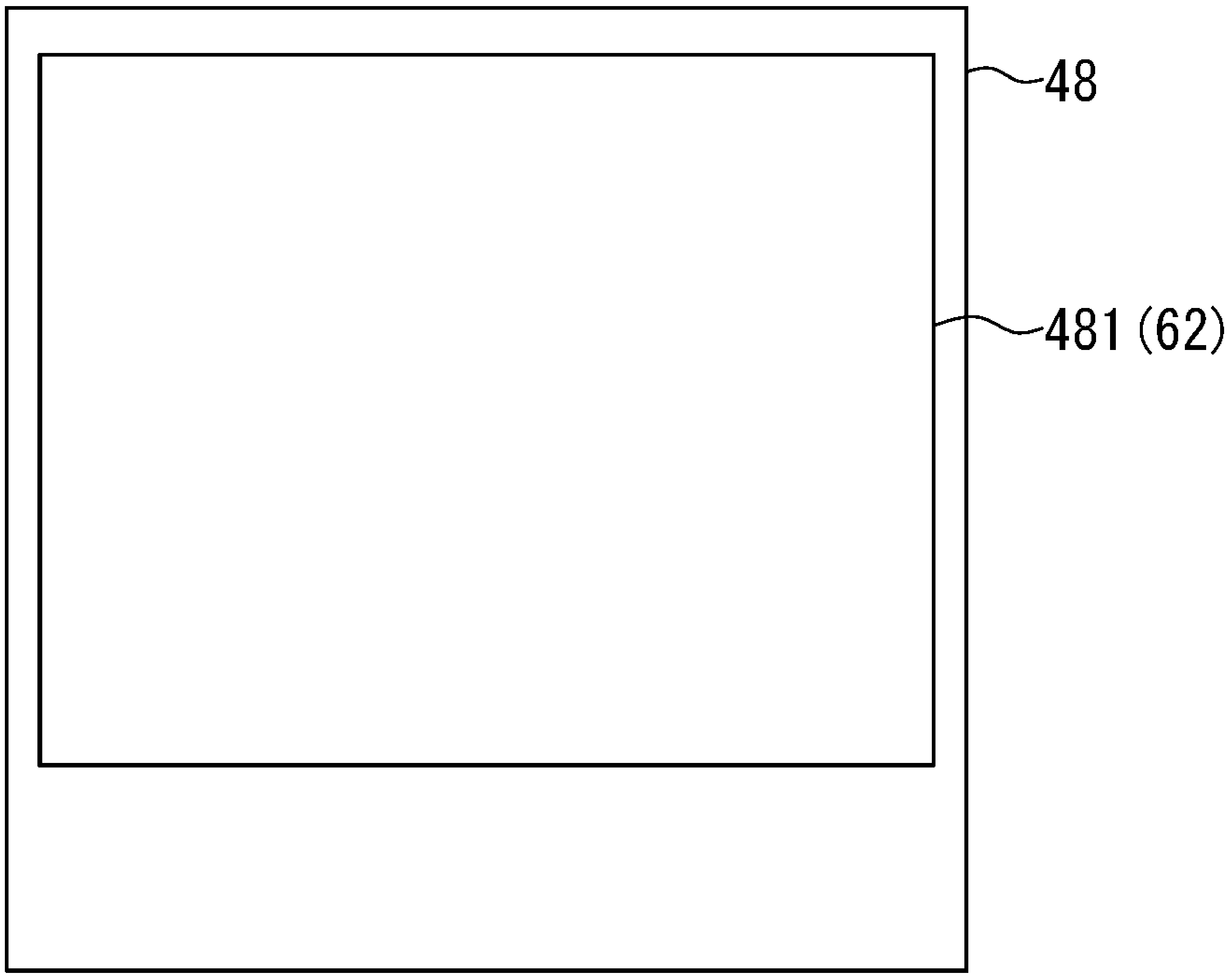


FIG. 11

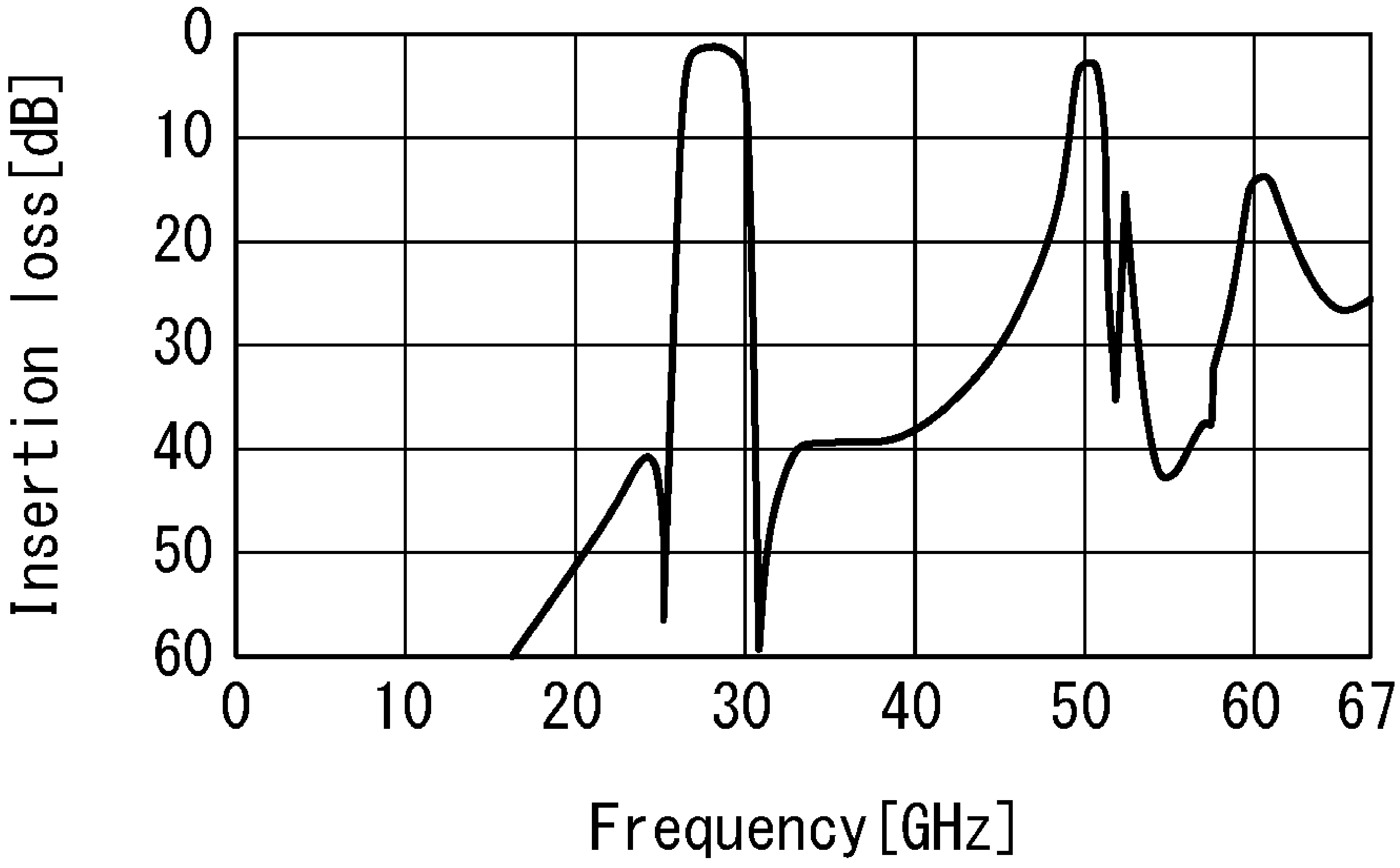


FIG. 12

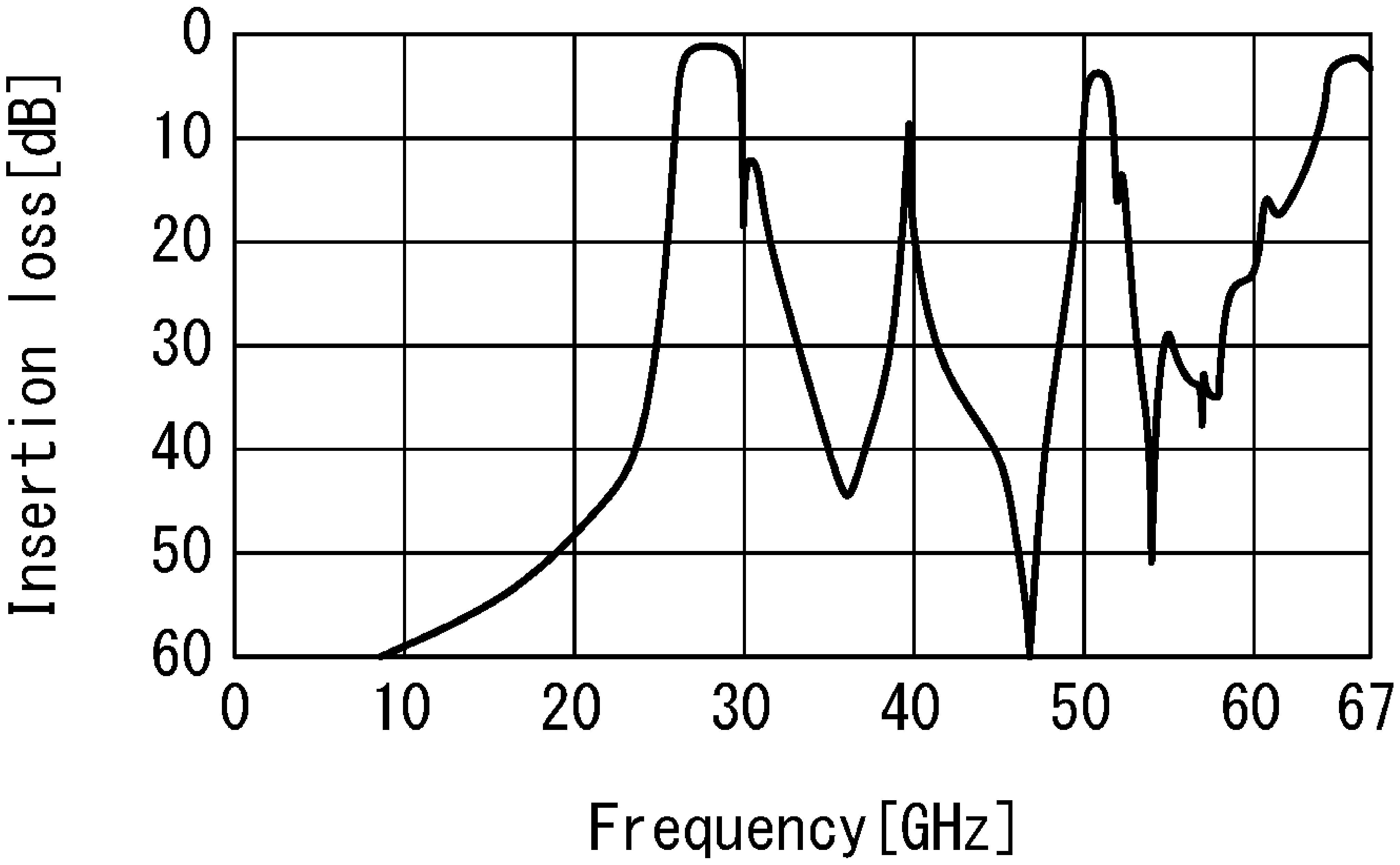
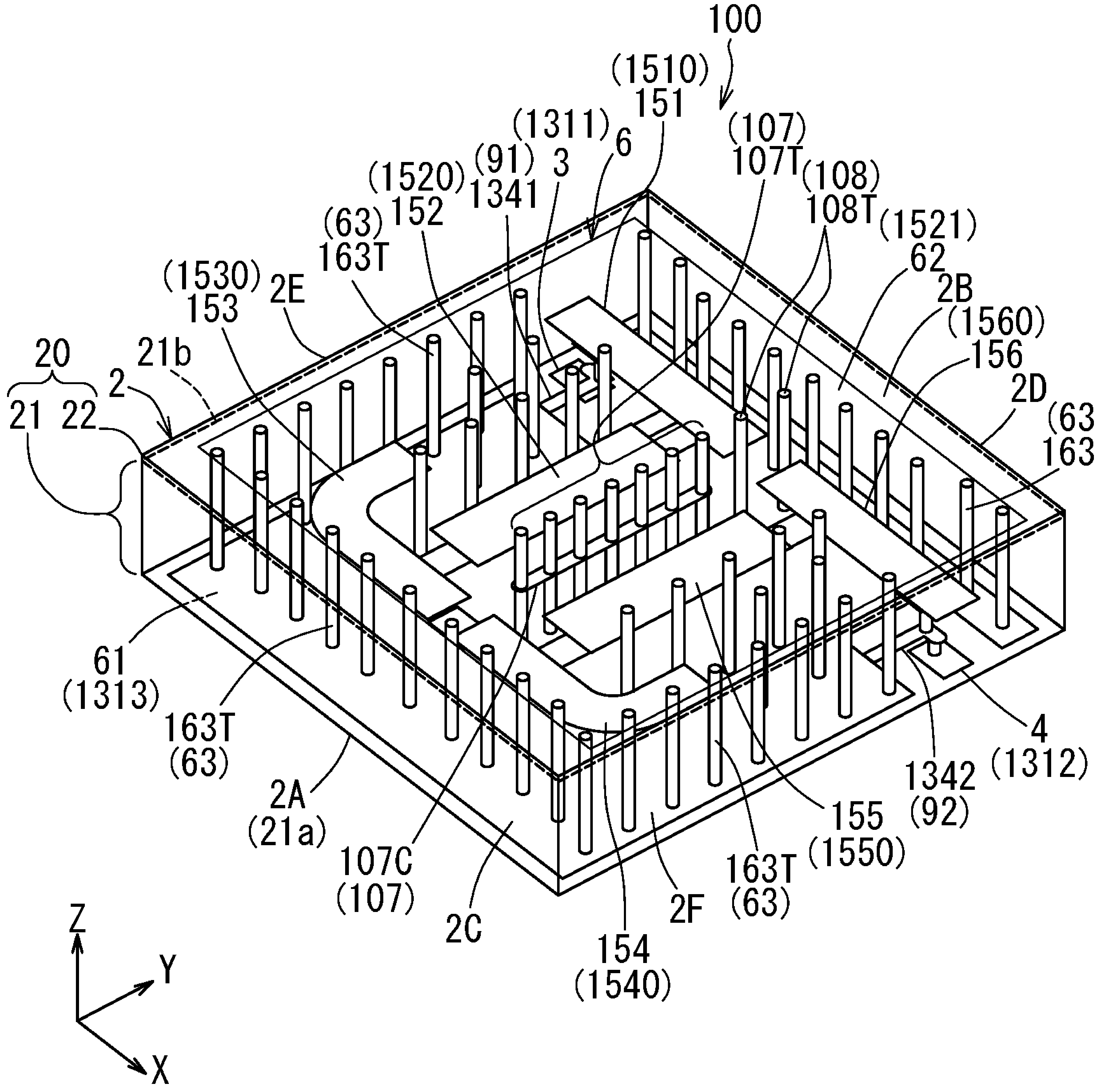


FIG. 13
RELATED ART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(63)
163T
(1521)
62
(1530)
153
2E
2B
(1560)
156
20
21b
2
21
22
2D
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(1313)
163T
(63)
2A
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107C
(107)
2C
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(92)
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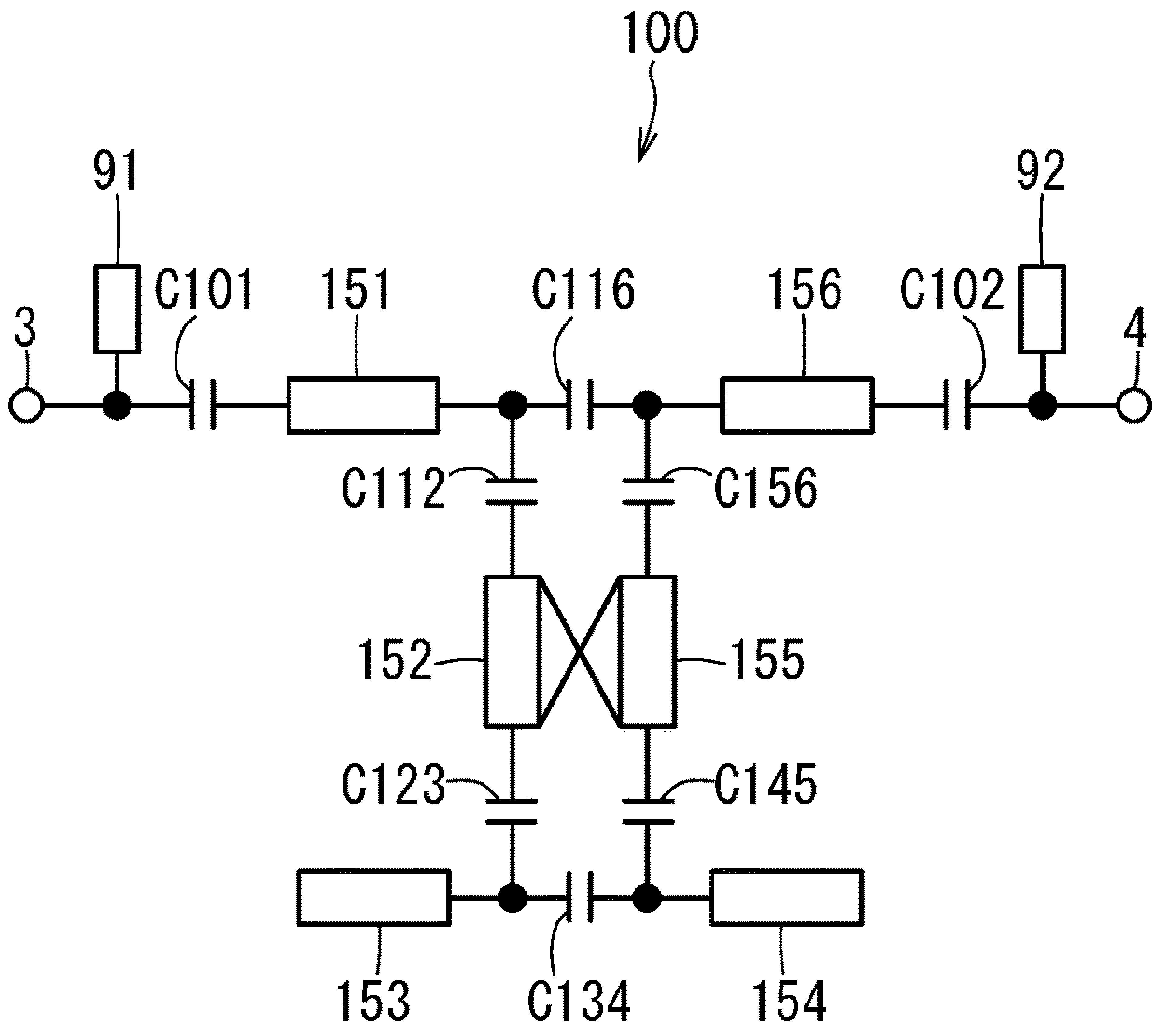
(1312)
Z
Y
X

FIG. 14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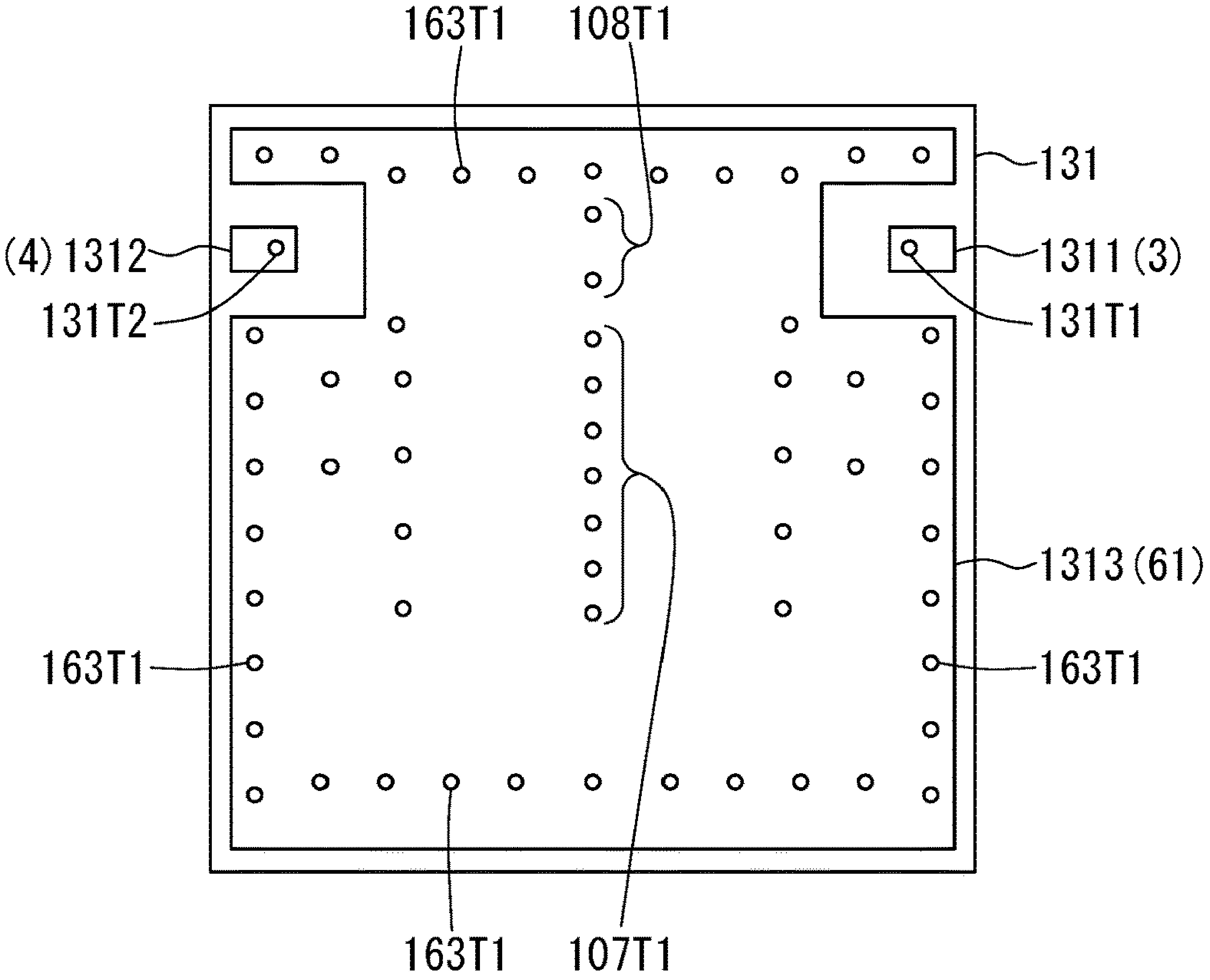
C134
154

FIG. 15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107T1

FIG. 16

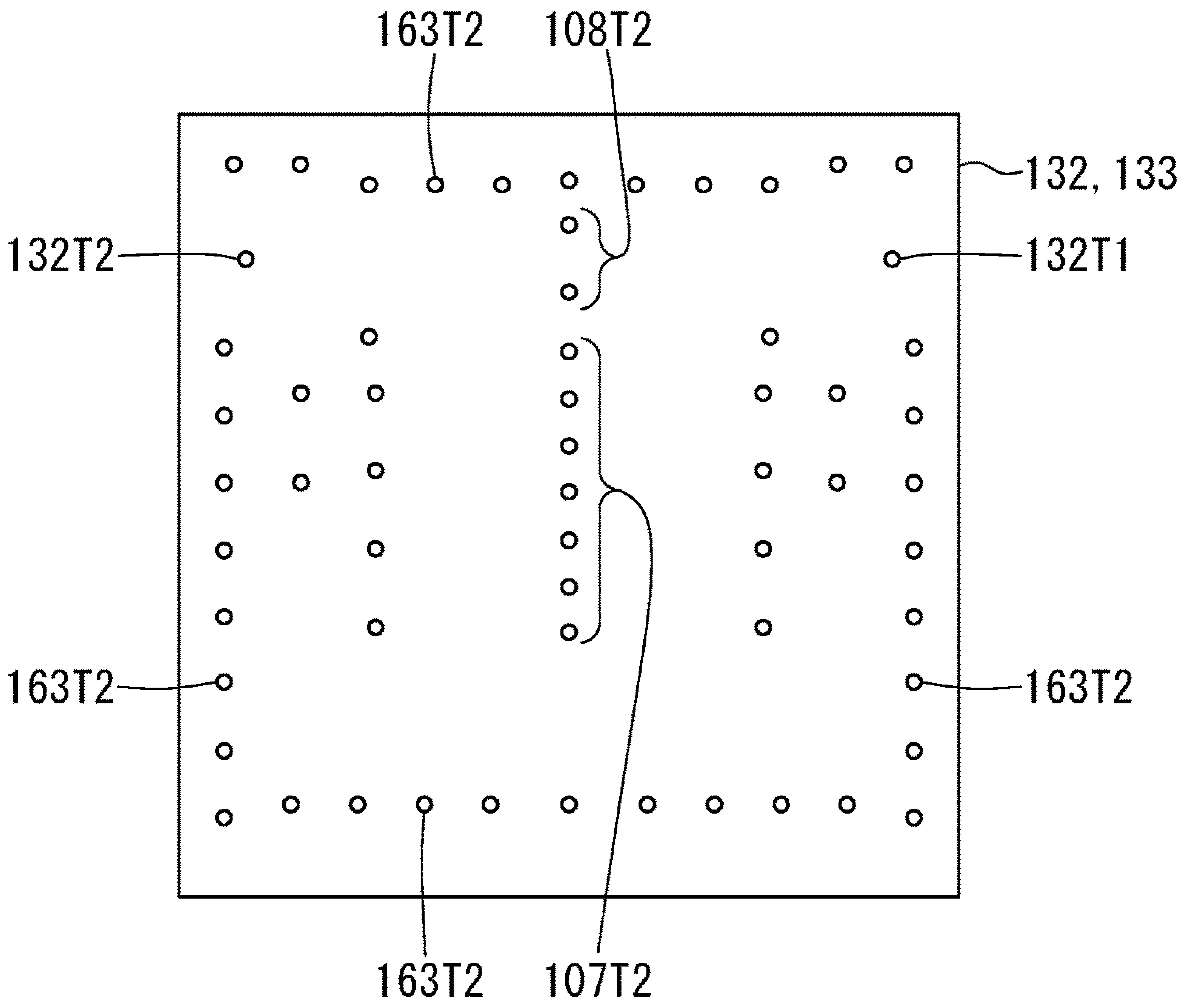
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FIG. 17

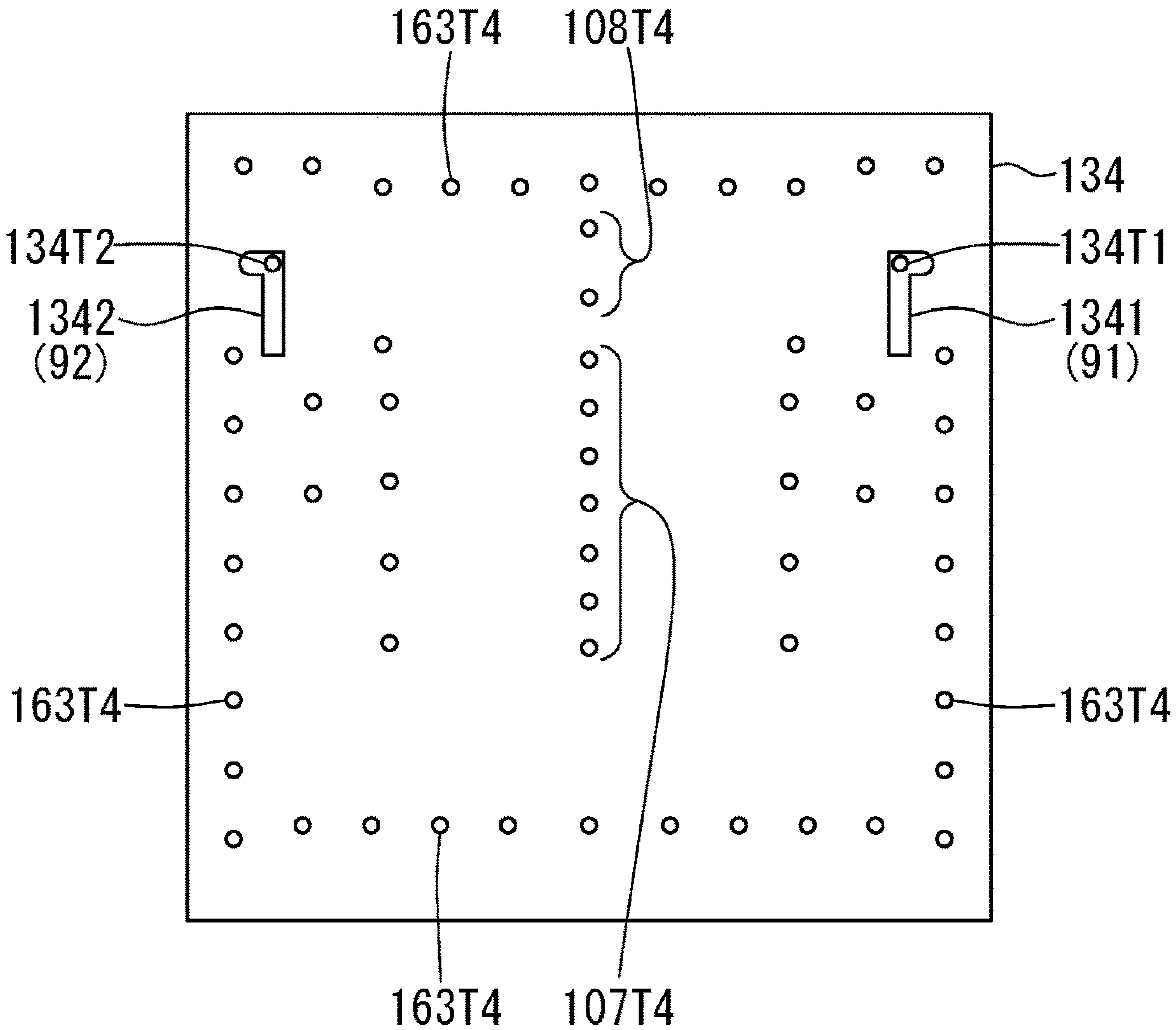
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FIG. 18

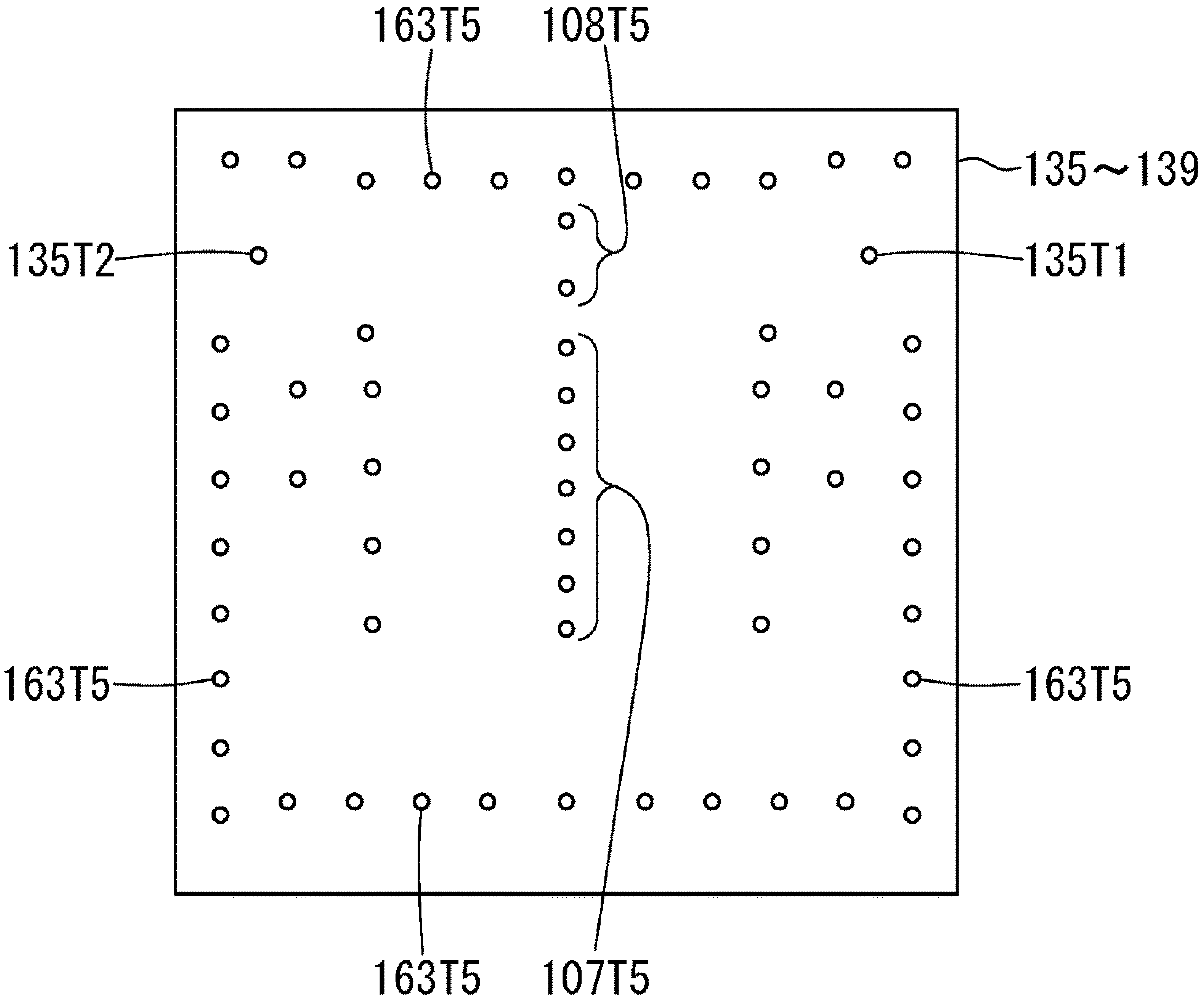
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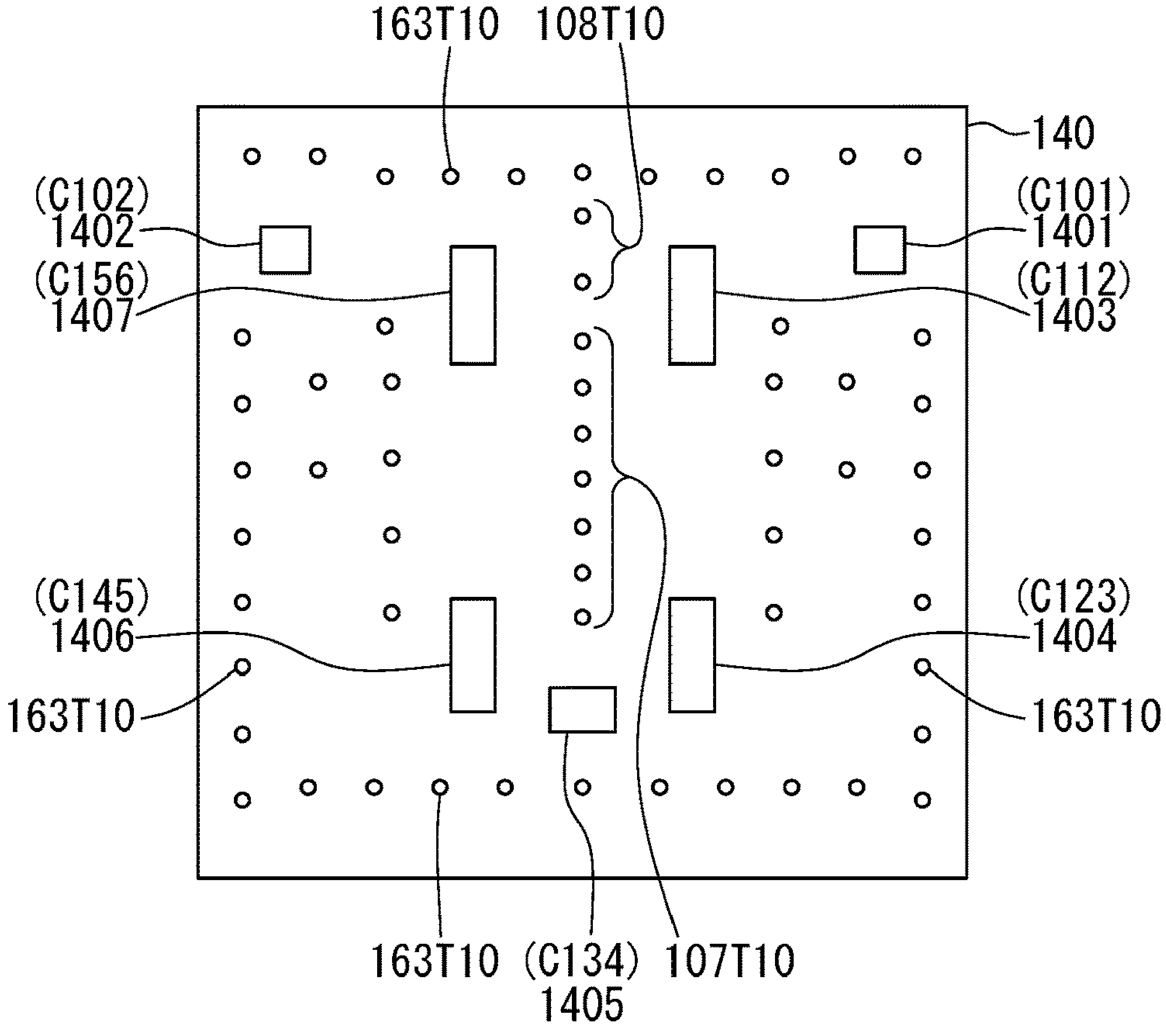
FIG. 19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(C134)
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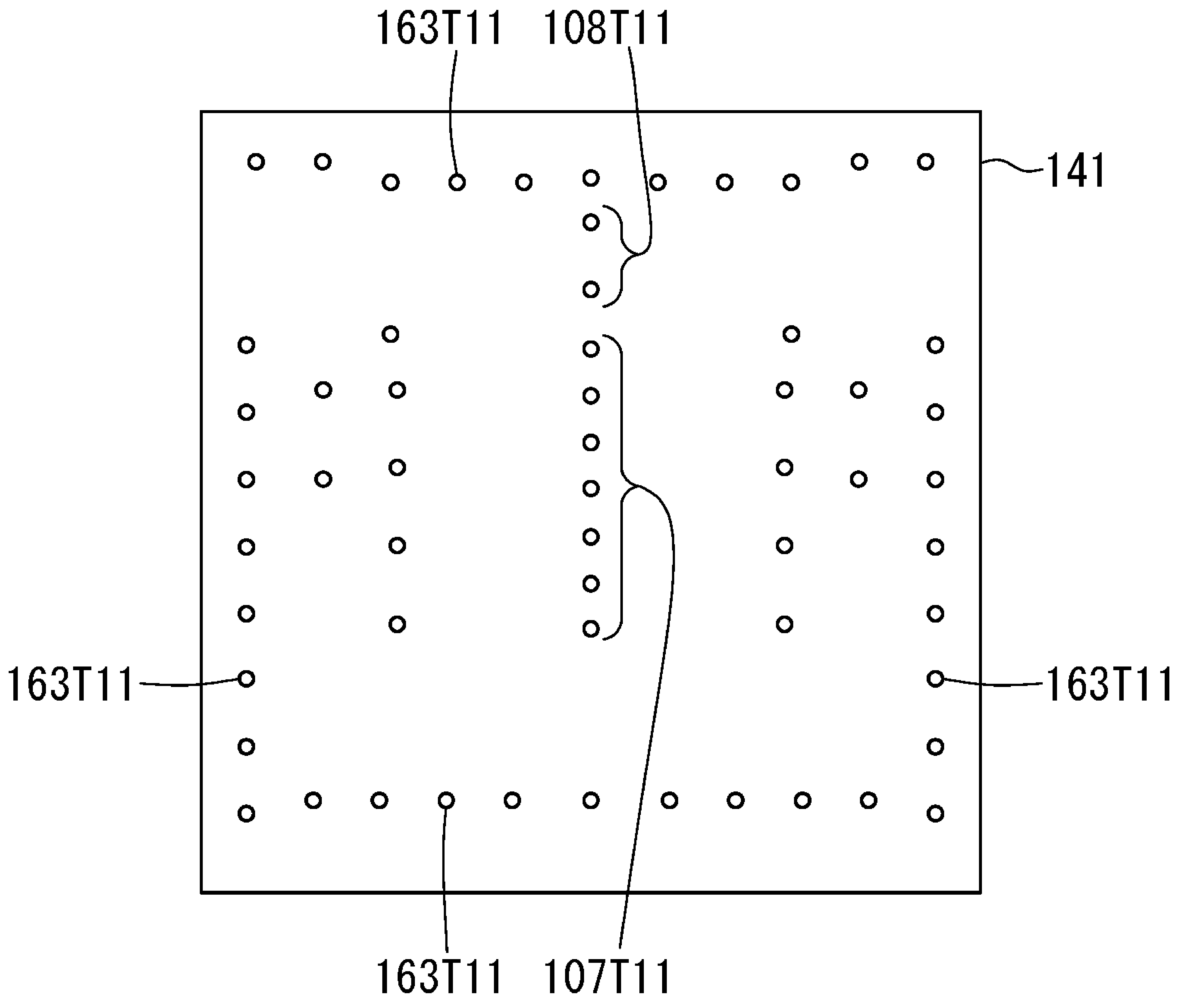
FIG. 20



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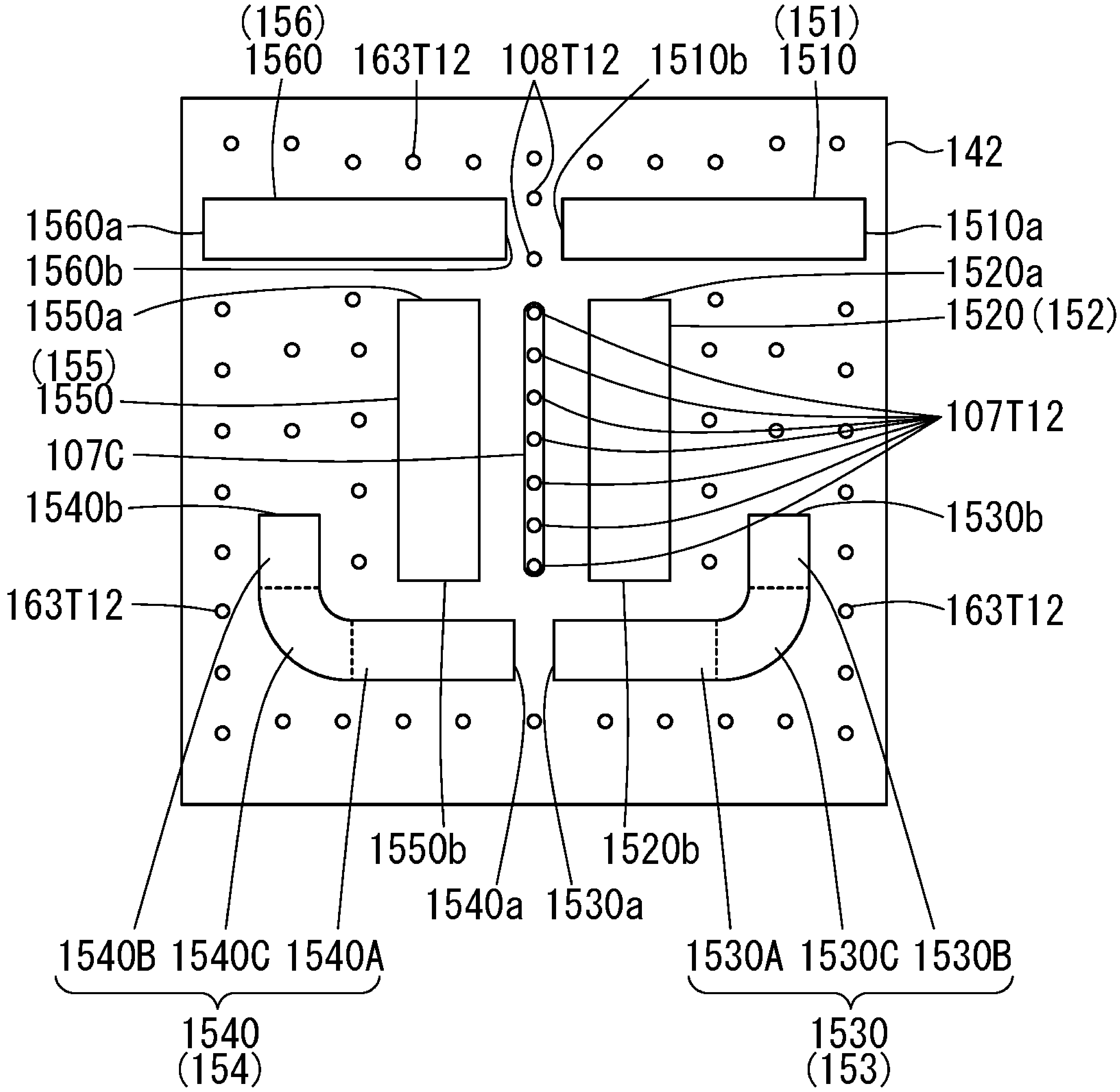
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1540b
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1510a
1520a
1520 (152)
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1530
(153)

FIG. 22

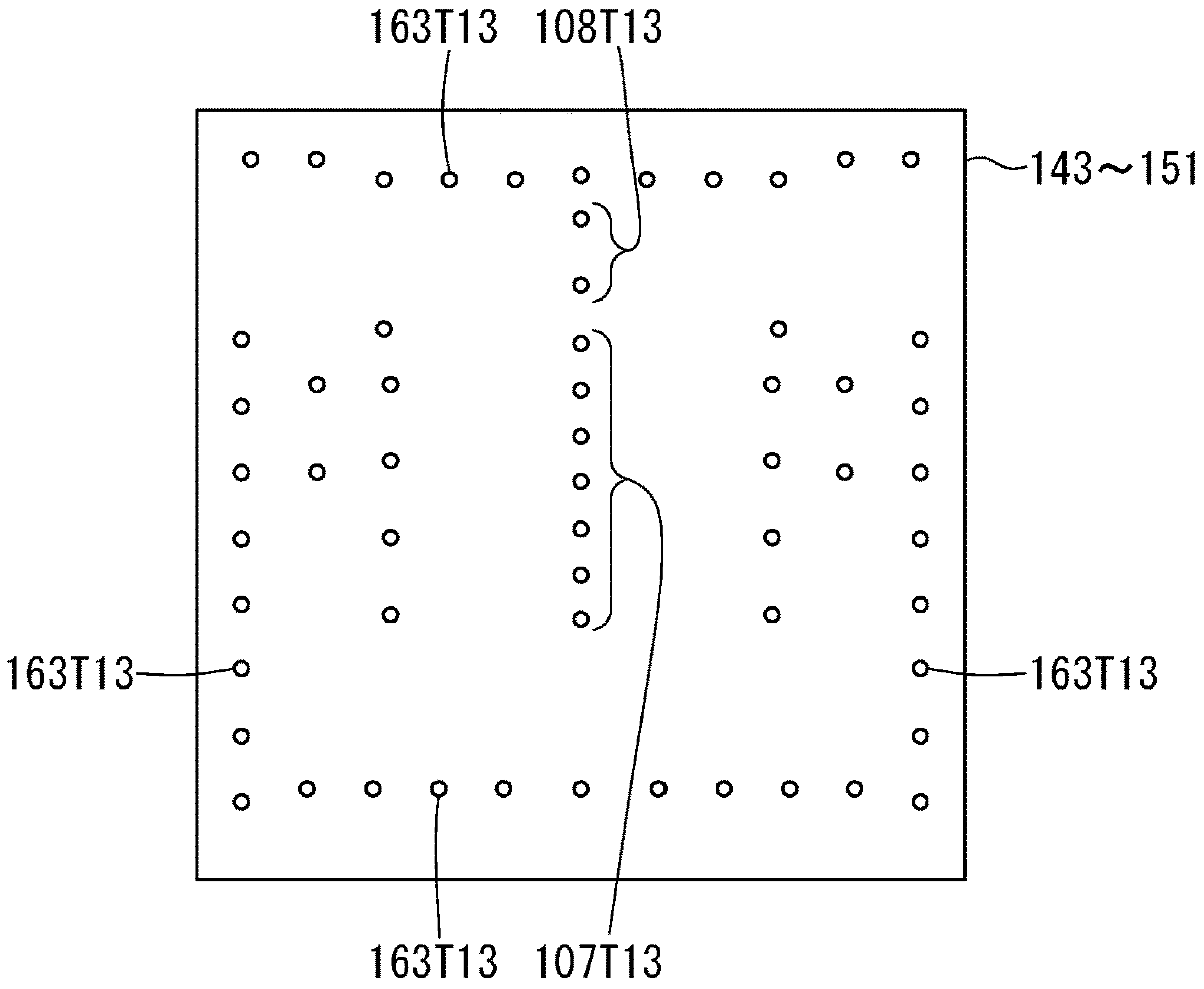
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FIG. 23

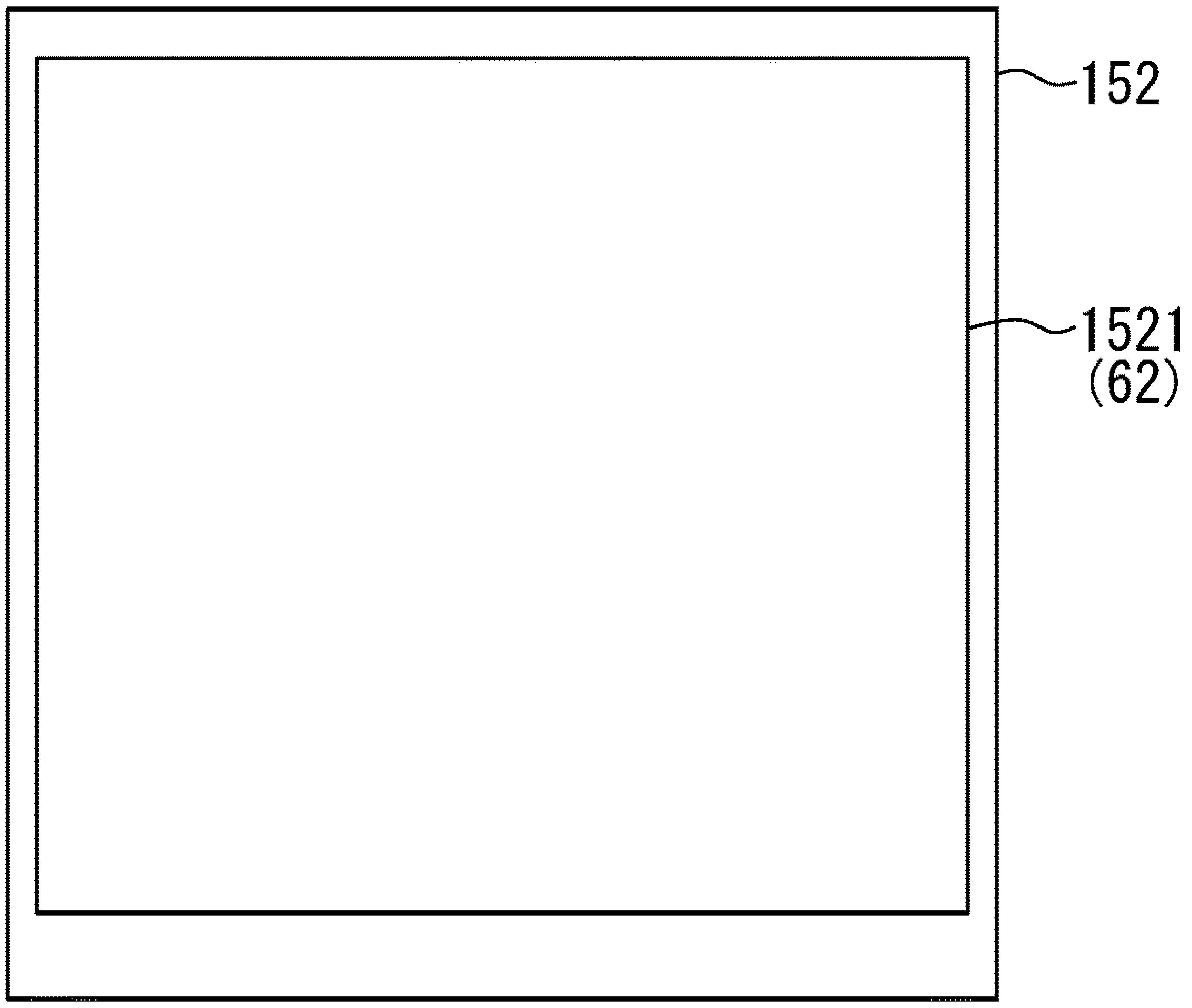
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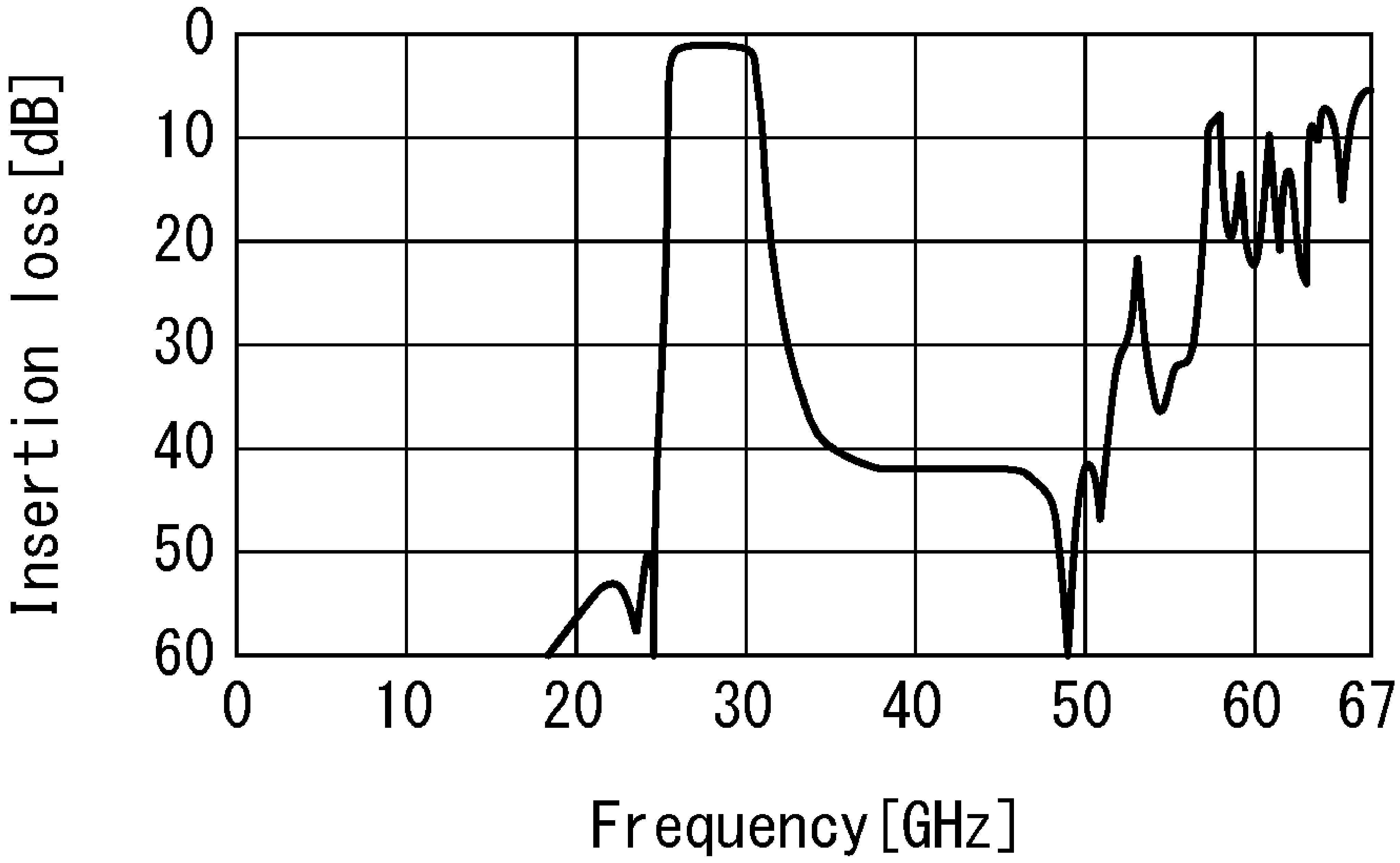
FIG. 24



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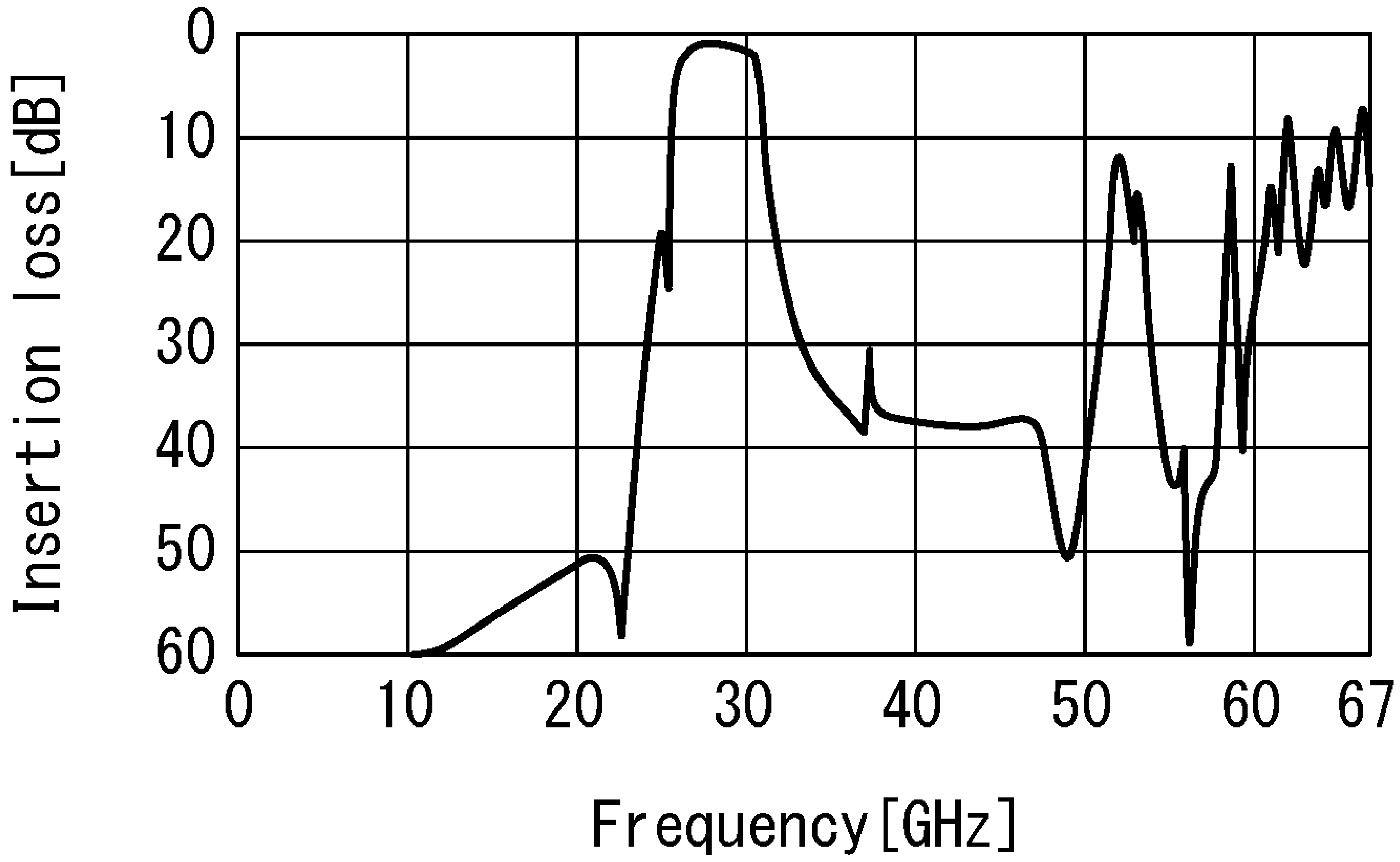
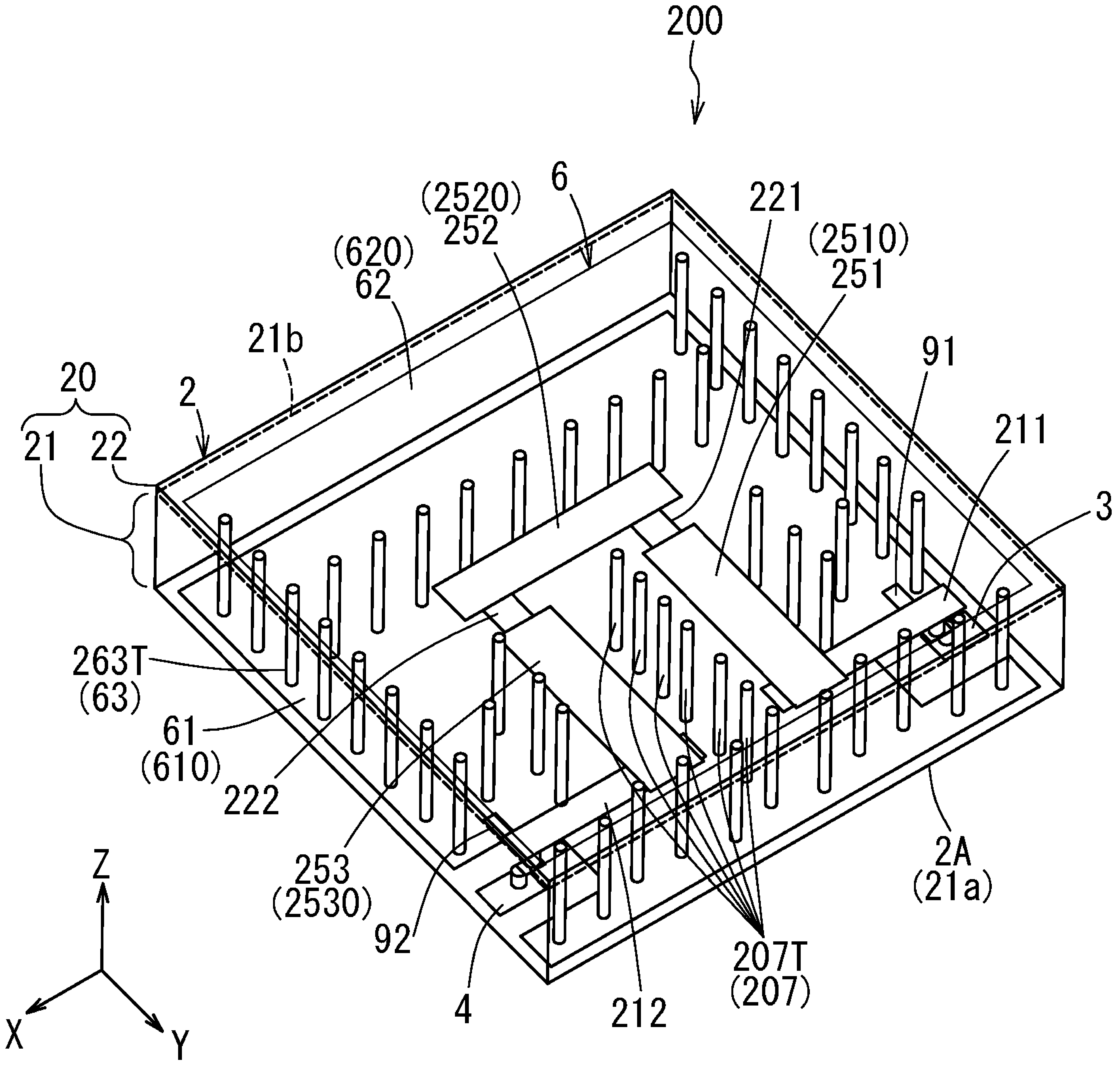


FIG. 26
RELATED ART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X
Y

FIG. 27

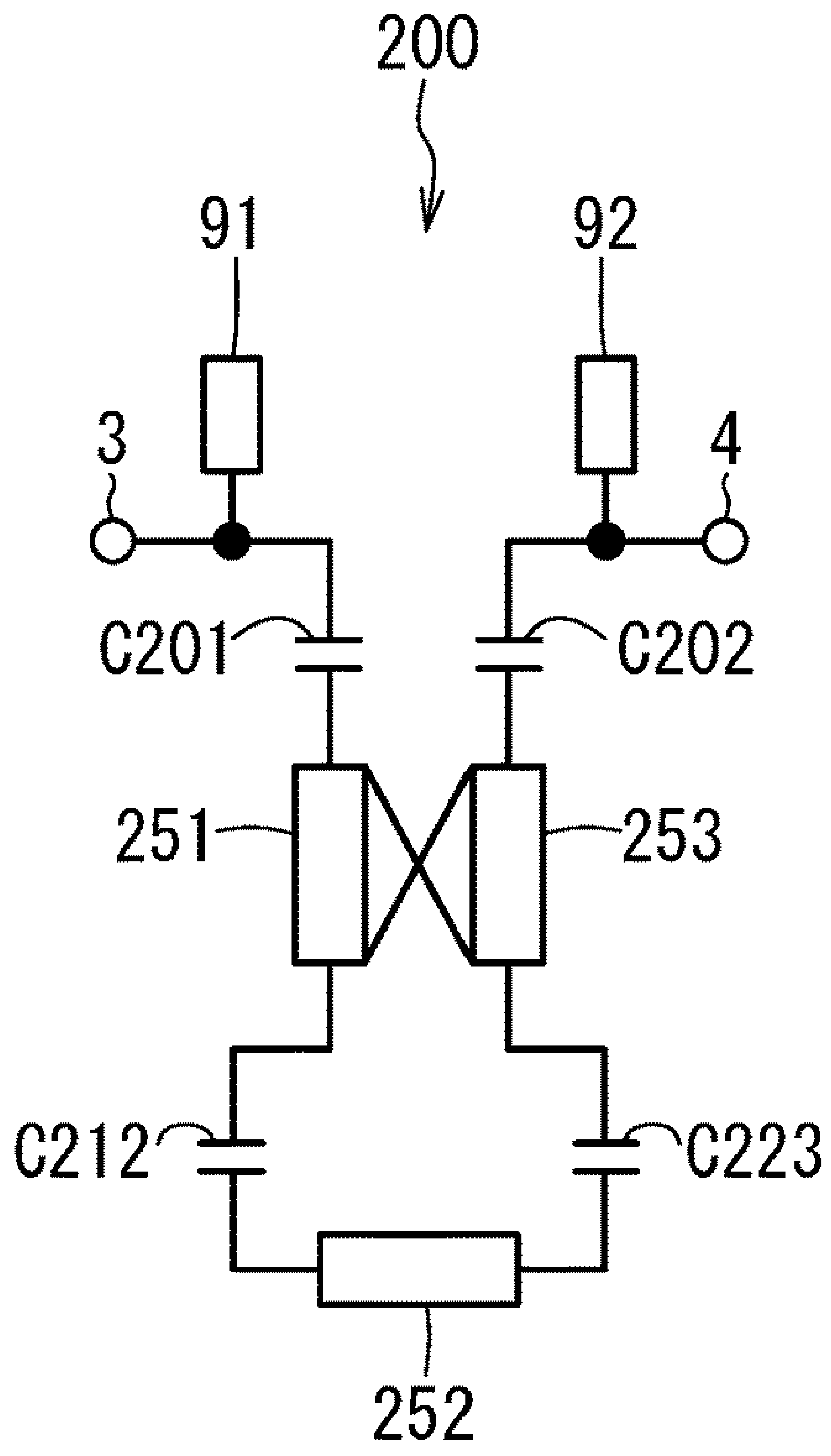
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FIG. 28

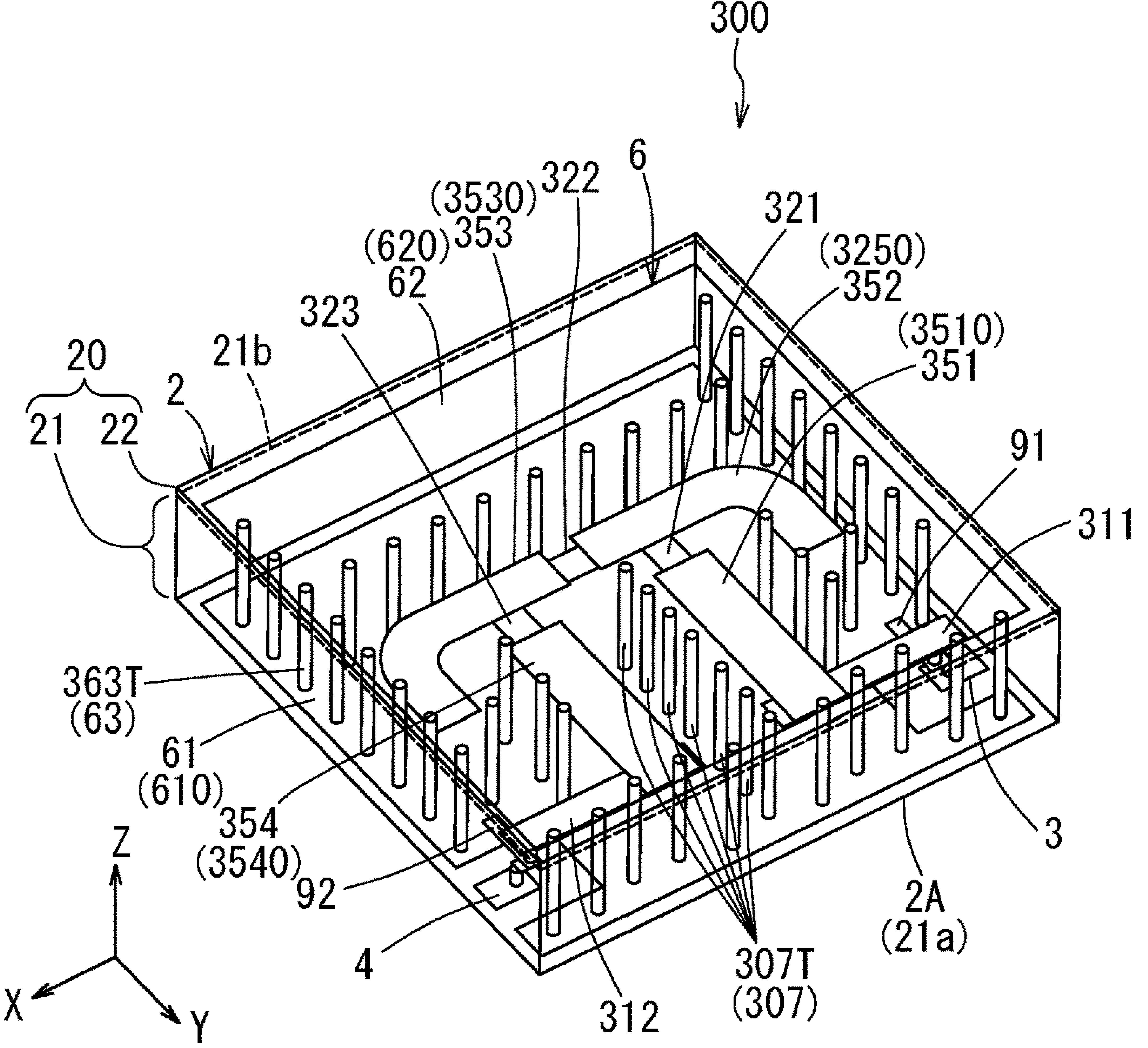
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FIG. 29

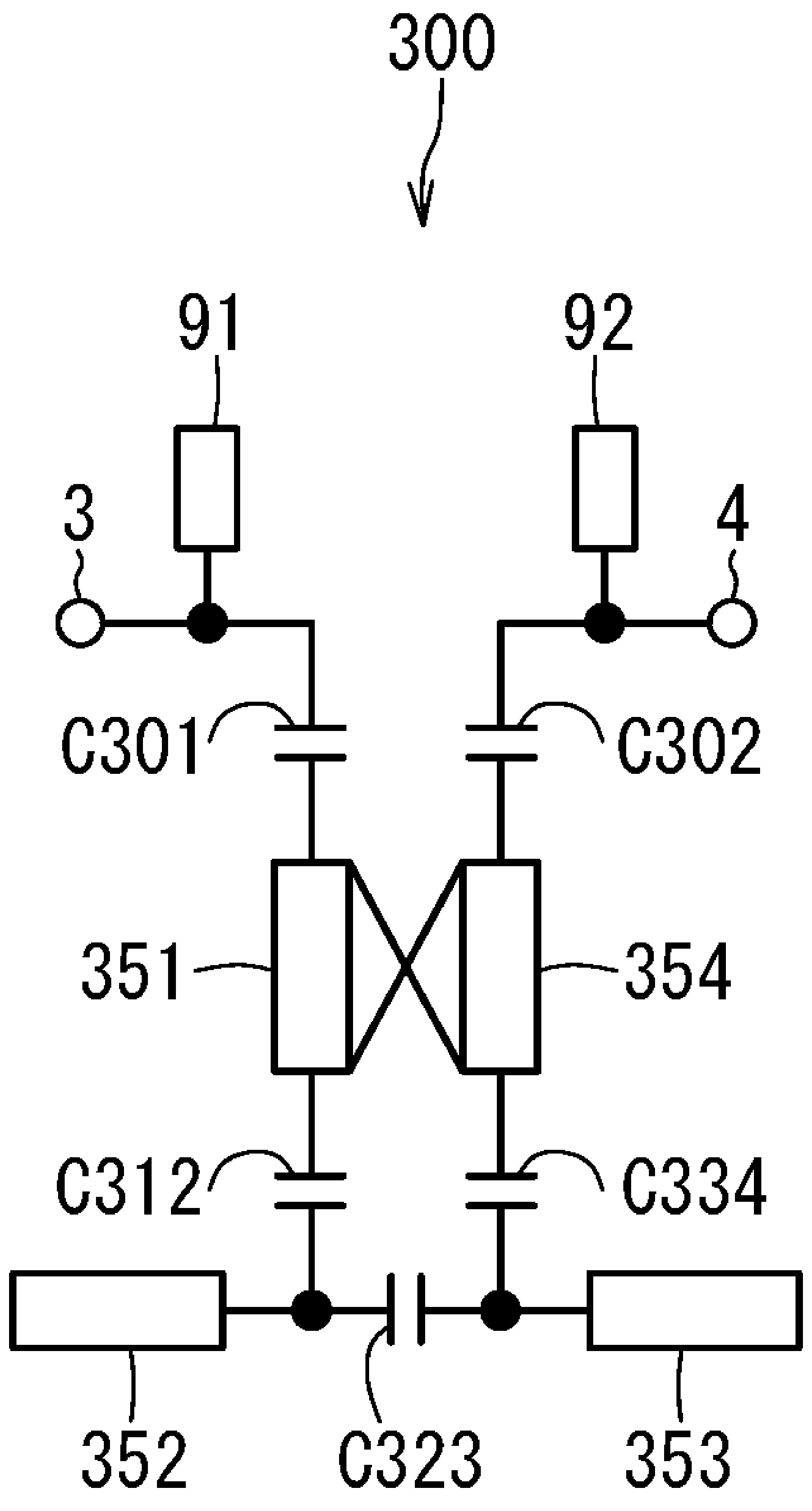

FIG. 30

BAND-PASS FILTER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a band-pass filter including a plurality of resonators and a shield.

2. Description of the Related Art

The standardization of fifth-generation mobile communication systems (hereinafter referred to as 5G) is currently ongoing. For 5G, the use of frequency bands of 10 GHz or higher, particularly a quasi-millimeter wave band of 10 to 30 GHz and a millimeter wave band of 30 to 300 GHz, is being studied to expand the frequency band.

One of electronic components used in a communication apparatus is a band-pass filter including a plurality of resonators. Each of the plurality of resonators includes, for example, a conductor portion that is long in one direction. To avoid electromagnetic radiation to the surroundings, some band-pass filters are configured so that the plurality of resonators are surrounded by a shield.

JP2006-311100A describes a chip-type multistage filter device usable in quasi-millimeter and millimeter wave bands. The chip-type multistage filter device includes a multilayer substrate, first and second surface ground electrodes, first and second internal ground electrodes, and first and second λ/2 resonator electrodes. The multilayer substrate is formed by stacking a plurality of dielectric layers. The multilayer substrate has first and second main surfaces opposed to each other, and first to fourth side surfaces connecting the first and second main surfaces. The first side surface and the second side surface are opposed to each other. The first surface ground electrode is disposed on the first side surface. The second surface ground electrode is disposed on the second side surface. The first internal ground electrode is disposed on one of the dielectric layers of the multilayer substrate that is relatively close to the first main surface. The second internal ground electrode is disposed on another one of the dielectric layers of the multilayer substrate that is relatively close to the second main surface. The first and second λ/2 resonator electrodes are disposed in an area surrounded by the first and second surface ground electrodes and the first and second internal ground electrodes.

The chip-type multistage filter device described in JP2006-311100A further includes a via hole conductor and a capacitance unit. The via hole conductor is formed to run through at least some of the dielectric layers so that the first and second internal ground electrodes are electrically connected to each other. The first and second λ/2 resonator electrodes are opposed to each other with the via hole conductor interposed therebetween. The capacitance unit is disposed within the multilayer substrate to add a coupling capacitance to between the first and second λ/2 resonator electrodes.

In a band-pass filter that is configured so that a plurality of resonators are surrounded by a shield, the shield and a dielectric material inside the shield constitute a structure similar to a waveguide, thereby generating at least one propagation mode for electromagnetic waves. Such a propagation mode for electromagnetic waves will hereinafter be referred to as a waveguide mode. In the band-pass filter, disadvantageously, the waveguide mode produces unwanted resonance having a resonance frequency in a frequency region above the passband, thus degrading the attenuation characteristic in the frequency region above the passband. For a band-pass filter that is designed to have a passband in the quasi-millimeter or millimeter wave band, the above-described problem is particularly noticeable because even the resonance frequency of a waveguide mode that is the lowest in resonance frequency (hereinafter, referred to as a lowest-order waveguide mode) is relatively close to the passband.

The resonance frequency of the lowest-order waveguide mode varies depending on the shape of the space defined by the shield. Typically, the larger the space, the lower the resonance frequency of the lowest-order waveguide mode.

JP 2006-311100A describes that resonance caused by outside shape can be reduced by the via hole conductor. The resonance caused by the outside shape corresponds to resonance caused by the above-described waveguide mode.

However, the filter device described in JP 2006-311100A has the following problem. In the filter device, the via hole conductor is disposed between the two λ/2 resonator electrodes that are adjacent to each other in circuit configuration and are capacitively coupled to each other. Typically, in a band-pass filter in which two resonators adjacent to each other in circuit configuration are configured to be coupled to each other, strong coupling is required between such two resonators. The filter device described in JP 2006-311100A has the problem that the production of strong capacitive coupling between two λ/2 resonator electrodes that are adjacent to each other in circuit configuration and the placement of the via hole conductor between such two λ/2 resonator electrodes are difficult to achieve at the same time without a deterioration in the characteristics of the band-pass filter.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a band-pass filter including a plurality of resonators and a shield and having favorable characteristics.

A band-pass filter of the present invention includes: a main body formed of a dielectric; a first input/output port and a second input/output port integrated with the main body; three or more resonators; a shield; and a partition. The three or more resonators are provided within the main body, located between the first input/output port and the second input/output port in circuit configuration, and configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. The shield is formed of a conductor and integrated with the main body. The partition is formed of a conductor, provided within the main body, and electrically connected to the shield.

The shield includes a first portion and a second portion spaced from each other in a first direction, and a connecting portion connecting the first and second portions. The first portion, the second portion and the connecting portion are arranged to surround the three or more resonators.

The three or more resonators include a first resonator and a second resonator that are configured to be magnetically coupled to each other although not adjacent to each other in circuit configuration. The first resonator includes a first resonator conductor portion formed of a conductor. The second resonator includes a second resonator conductor portion formed of a conductor. Each of the first and second resonator conductor portions extends in a direction intersecting the first direction.

The partition is in contact with the first portion and the second portion. At least part of the partition extends to pass between the first resonator conductor portion and the second resonator conductor portion.

In the band-pass filter of the present invention, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration may be capacitive coupling.

In the band-pass filter of the present invention, each of the three or more resonators may be a resonator with open ends.

In the band-pass filter of the present invention, the partition may extend in the first direction and connect the first portion and the second portion via a shortest path.

In the band-pass filter of the present invention, the first resonator may be a resonator that is the closest to the first input/output port in circuit configuration, and the second resonator may be a resonator that is the closest to the second input/output port in circuit configuration. In this case, the three or more resonators may be five resonators.

In the band-pass filter of the present invention, the first resonator may be a resonator that is the second closest to the first input/output port in circuit configuration, and the second resonator may be a resonator that is the second closest to the second input/output port in circuit configuration. In this case, the three or more resonators may be six resonators.

The band-pass filter of the present invention may further include a notch filter section for attenuating a signal of a predetermined frequency higher than the passband.

In the band-pass filter of the present invention, the main body may include a multilayer stack composed of a plurality of dielectric layers stacked together in the first direction. In such a case, the multilayer stack may include a main portion composed of two or more dielectric layers stacked together, among the plurality of dielectric layers. The main portion has a first end face and a second end face located at opposite ends in the first direction. The first portion may be formed of a first conductor layer disposed on the first end face. The second portion may be formed of a second conductor layer disposed on the second end face. The partition may run through the two or more dielectric layers. The partition may include a plurality of first through hole lines each running through the two or more dielectric layers. Each of the plurality of first through hole lines may include two or more through holes connected in series. The connecting portion of the shield may include a plurality of second through hole lines each running through the two or more dielectric layers. Each of the plurality of second through hole lines may include two or more through holes connected in series.

In the band-pass filter of the present invention, when the main body includes the aforementioned multilayer stack, the first resonator conductor portion and the second resonator conductor portion may be located at the same position in the multilayer stack in the first direction.

In the band-pass filter of the present invention, the partition divides the space defined by the shield into a space in which the first resonator conductor portion is located and a space in which the second resonator conductor portion is located. The present invention thereby makes the resonance frequency of the lowest-order waveguide mode higher than in the case without the partition. Further, according to the present invention, magnetic coupling is established between the first resonator and the second resonator that are not adjacent to each other in circuit configuration. This enables creation of an attenuation pole in at least one of two frequency regions in a frequency response of insertion loss. One of the two frequency regions is a first passband-vicinity region, which is a frequency region close to the passband and lower than the passband, and the other is a second passband-vicinity region, which is a frequency region close to the passband and higher than the passband. The present invention thus enables realization of a band-pass filter including a plurality of resonators and a shield and having favorable characteristics.

Other and further objects, features and advantages of the invention will appear more fully from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view illustrating the structure of a band-pass filter according to a first embodiment of the invention.

FIG. **2** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the first embodiment of the invention.

FIG. **3** is an explanatory diagram illustrating a patterned surface of a first dielectric layer of a multilayer stack shown in FIG. **1**.

FIG. **4** is an explanatory diagram illustrating a patterned surface of a second dielectric layer of the multilayer stack shown in FIG. **1**.

FIG. **5** is an explanatory diagram illustrating a patterned surface of a third dielectric layer of the multilayer stack shown in FIG. **1**.

FIG. **6** is an explanatory diagram illustrating a patterned surface of a fourth dielectric layer of the multilayer stack shown in FIG. **1**.

FIG. **7** is an explanatory diagram illustrating a patterned surface of each of a fifth to a seventh dielectric layer of the multilayer stack shown in FIG. **1**.

FIG. **8** is an explanatory diagram illustrating a patterned surface of an eighth dielectric layer of the multilayer stack shown in FIG. **1**.

FIG. **9** is an explanatory diagram illustrating a patterned surface of a ninth dielectric layer of the multilayer stack shown in FIG. **1**.

FIG. **10** is an explanatory diagram illustrating a patterned surface of each of a tenth to a seventeenth dielectric layer of the multilayer stack shown in FIG. **1**.

FIG. **11** is an explanatory diagram illustrating a patterned surface of an eighteenth dielectric layer of the multilayer stack shown in FIG. **1**.

FIG. **12** is a characteristic diagram illustrating an example of the frequency response of the insertion loss of the band-pass filter according to the first embodiment of the invention.

FIG. **13** is a characteristic diagram illustrating an example of the frequency response of the insertion loss of a band-pass filter of a first comparative example.

FIG. **14** is a perspective view illustrating the structure of a band-pass filter according to a second embodiment of the invention.

FIG. **15** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the second embodiment of the invention.

FIG. **16** is an explanatory diagram illustrating a patterned surface of a first dielectric layer of the multilayer stack shown in FIG. **14**.

FIG. **17** is an explanatory diagram illustrating a patterned surface of each of a second and a third dielectric layer of the multilayer stack shown in FIG. **14**.

FIG. **18** is an explanatory diagram illustrating a patterned surface of a fourth dielectric layer of the multilayer stack shown in FIG. **14**.

FIG. **19** is an explanatory diagram illustrating a patterned surface of each of a fifth to a ninth dielectric layer of the multilayer stack shown in FIG. **14**.

FIG. **20** is an explanatory diagram illustrating a patterned surface of a tenth dielectric layer of the multilayer stack shown in FIG. **14**.

FIG. **21** is an explanatory diagram illustrating a patterned surface of an eleventh dielectric layer of the multilayer stack shown in FIG. **14**.

FIG. **22** is an explanatory diagram illustrating a patterned surface of a twelfth dielectric layer of the multilayer stack shown in FIG. **14**.

FIG. **23** is an explanatory diagram illustrating a patterned surface of each of a thirteenth to a twenty-first dielectric layer of the multilayer stack shown in FIG. **14**.

FIG. **24** is an explanatory diagram illustrating a patterned surface of a twenty-second dielectric layer of the multilayer stack shown in FIG. **14**.

FIG. **25** is a characteristic diagram illustrating an example of the frequency response of the insertion loss of the band-pass filter according to the second embodiment of the invention.

FIG. **26** is a characteristic diagram illustrating an example of the frequency response of the insertion loss of a band-pass filter of a second comparative example.

FIG. **27** is a perspective view illustrating the structure of a band-pass filter according to a third embodiment of the invention.

FIG. **28** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the third embodiment of the invention.

FIG. **29** is a perspective view illustrating the structure of a band-pass filter according to a fourth embodiment of the invention.

FIG. **30** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the fourth embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

Preferred embodiments of the present invention will now be described in detail with reference to the drawings. First, reference is made to FIG. **1** and FIG. **2** to describe the configuration of a band-pass filter according to a first embodiment of the invention. FIG. **1** is a perspective view illustrating the structure of the band-pass filter according to the present embodiment. FIG. **2** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the present embodiment.

As shown in FIG. **1**, the band-pass filter **1** according to the present embodiment includes: a main body **2** formed of a dielectric; a first input/output port **3** and a second input/output port **4** integrated with the main body **2**; three or more resonators provided within the main body **2**; a shield **6**; a first partition **7**; and a second partition **8**. The shield **6** is formed of a conductor and integrated with the main body **2**. The shield **6** is connected to the ground. The shield **6** has the function of preventing electromagnetic radiation to the surroundings of the band-pass filter **1**. Each of the first partition **7** and the second partition **8** is formed of a conductor, provided within the main body **2** and electrically connected to the shield **6**. The first partition **7** corresponds to the partition in the present invention.

The main body **2** includes a multilayer stack **20** composed of a plurality of dielectric layers stacked together. Here, X, Y and Z directions are defined as shown in FIG. **1**. The X, Y and Z directions are orthogonal to one another. In the present embodiment, the direction in which the plurality of dielectric layers are stacked is the Z direction (the upward direction in FIG. **1**). The Z direction corresponds to the first direction in the present invention.

The main body **2** is shaped like a rectangular solid. The main body **2** has a first end face **2**A and a second end face **2**B located at opposite ends in the Z direction of the main body **2**, and further has four side surfaces **2**C, **2**D, **2**E and **2**F connecting the first end face **2**A and the second end face **2**B. The first end face **2**A is also the bottom surface of the main body **2**. The second end face **2**B is also the top surface of the main body **2**. The side surfaces **2**C and **2**D are located at opposite ends in the Y direction of the main body **2**. The side surfaces **2**E and **2**F are located at opposite ends in the X direction of the main body **2**.

The three or more resonators are located between the first input/output port **3** and the second input/output port **4** in circuit configuration. The three or more resonators are configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. As used herein, the phrase “in circuit configuration” is to describe layout in a circuit diagram, not in a physical configuration. Among the three or more resonators, a resonator that is the n-th closest to the first input/output port **3** in circuit configuration may also be referred to as the n-th stage resonator.

In the present embodiment, as shown in FIG. **2**, the three or more resonators are specifically five resonators **51**, **52**, **53**, **54** and **55**. The five resonators **51**, **52**, **53**, **54** and **55** are arranged in this order, from closest to farthest, from the first input/output port **3** in circuit configuration. The resonators **51** to **55** are configured so that the resonators **51** and **52** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators **52** and **53** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators **53** and **54** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, and the resonators **54** and **55** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other. In the present embodiment, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is specifically capacitive coupling. In the present embodiment, each of the resonators **51** to **55** is a resonator with open ends, and also a half-wave resonator.

The band-pass filter **1** includes a capacitor C**12** for establishing capacitive coupling between the resonators **51** and **52**, a capacitor C**23** for establishing capacitive coupling between the resonators **52** and **53**, a capacitor C**34** for establishing capacitive coupling between the resonators **53** and **54**, and a capacitor C**45** for establishing capacitive coupling between the resonators **54** and **55**.

In a band-pass filter including three or more resonators configured so that every two of the resonators adjacent to each other in circuit configuration are coupled to each other, electromagnetic coupling may be established between two resonators that are not adjacent to each other in circuit configuration. Such electromagnetic coupling between non-adjacent resonators will be referred to as cross coupling. As will be described in detail below, the band-pass filter **1** according to the present embodiment has two cross couplings.

In the present embodiment, among the five resonators **51** to **55**, the resonator **51**, which is the closest to the first input/output port **3** in circuit configuration, and the resonator **55**, which is the closest to the second input/output port **4** in circuit configuration, are magnetically coupled to each other although they are not adjacent to each other in circuit configuration. The resonator **51** corresponds to the first resonator in the present invention. The resonator **55** corresponds to the second resonator in the present invention.

Further, in the present embodiment, among the five resonators **51** to **55**, the resonator **52**, which is the second closest to the first input/output port **3** in circuit configuration, and the resonator **54**, which is the second closest to the second input/output port **4** in circuit configuration, are capacitively coupled to each other although they are not adjacent to each other in circuit configuration. In FIG. **2**, the capacitor symbol C**24** represents the capacitive coupling between the resonators **52** and **54**.

The band-pass filter **1** further includes a capacitor C**1** provided between the first input/output port **3** and the resonator **51**, and a capacitor C**2** provided between the second input/output port **4** and the resonator **55**.

The band-pass filter **1** further includes a notch filter section for attenuating a signal of a predetermined frequency (hereinafter referred to as notch frequency) higher than the passband. The notch filter section includes two lines **91** and **92** each formed of a conductor. Each of the lines **91** and **92** has a first end and a second end opposite to each other. The first end of the line **91** is connected to the first input/output port **3**, and the second end of the line **91** is open. The first end of the line **92** is connected to the second input/output port **4**, and the second end of the line **92** is open. Each of the lines **91** and **92** has a length of one quarter or nearly one quarter the wavelength corresponding to the notch frequency. Each of the lines **91** and **92** is a quarter-wave resonator that resonates at the notch frequency. The notch frequency is, for example, twice the center frequency of the passband of the band-pass filter **1**.

The shield **6** includes a first portion **61** and a second portion **62** spaced from each other in the first direction, i.e., the Z direction, and a connecting portion **63** connecting the first portion **61** and the second portion **62**. The first portion **61**, the second portion **62** and the connecting portion **63** are arranged to surround the five resonators **51** to **55**.

The multilayer stack **20** includes a main portion **21** and a coating portion **22**. The main portion **21** is composed of two or more dielectric layers stacked together, among the plurality of dielectric layers constituting the multilayer stack **20**. The coating portion **22** is composed of one or more dielectric layers other than the two or more dielectric layers constituting the main portion **21**, among the plurality of dielectric layers constituting the multilayer stack **20**. The main portion **21** has a first end face **21***a* and a second end face **21***b* located at opposite ends in the direction in which the two or more dielectric layers are stacked. The coating portion **22** covers the second end face **21***b*. The first end face **21***a* of the main portion **21** coincides with the first end face **2**A of the main body **2**. The second end face **21***b* of the main portion **21** is located within the main body **2**.

The first portion **61** is formed of a first conductor layer **313** disposed on the first end face **21***a*. The second portion **62** is formed of a second conductor layer **481** disposed on the second end face **21***b*. The second portion **62** is interposed between the main portion **21** and the coating portion **22**.

The resonator **51** includes a resonator conductor portion **510** formed of a conductor. The resonator **52** includes a resonator conductor portion **520** formed of a conductor. The resonator **53** includes a resonator conductor portion **530** formed of a conductor. The resonator **54** includes a resonator conductor portion **540** formed of a conductor. The resonator **55** includes a resonator conductor portion **550** formed of a conductor. The resonator conductor portion **510** corresponds to the first resonator conductor portion in the present invention. The resonator conductor portion **550** corresponds to the second resonator conductor portion in the present invention.

Each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** extends in a direction intersecting the first direction or the Z direction. In the present embodiment, specifically, each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** extends in a direction orthogonal to the first direction or the Z direction.

Each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** has a first end and a second end opposite to each other. As mentioned above, each of the resonators **51** to **55** is a resonator with open ends. Thus, both of the first and second ends of each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** are open. Each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** has a length of one half or nearly one half the wavelength corresponding to the center frequency of the passband of the band-pass filter **1**.

The partition **7** is in contact with the first portion **61** and the second portion **62**. At least part of the partition **7** extends to pass between the resonator conductor portion **510** and the resonator conductor portion **550**. In the present embodiment, specifically, the first partition **7** extends in the first direction, i.e., the Z direction. The first partition **7** connects the first portion **61** and the second portion **62** via the shortest path. To be more specific, the length of the first partition **7** in the Z direction is equal to the distance between the first portion **61** and the second portion **62**.

The first partition **7** runs through the two or more dielectric layers constituting the main portion **21**. In the present embodiment, the first partition **7** includes a plurality of through hole lines **7**T each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **7**T correspond to the plurality of first through hole lines in the present invention. In FIG. **1**, each through hole line **7**T is represented by a circular column. Each of the through hole lines **7**T includes two or more through holes connected in series. Each of the through hole lines **7**T extends in the Z direction. The through hole lines **7**T are arranged to be adjacent to each other in the Y direction. In the present embodiment, the number of the through hole lines **7**T is five.

The second partition **8** extends to pass through the area surrounded by the resonator conductor portions **520**, **530** and **540**, and is in contact with the first portion **61** and the second portion **62**. In the present embodiment, specifically, the second partition **8** extends in the first direction, i.e., the Z direction. The second partition **8** connects the first portion **61** and the second portion **62** via the shortest path. To be more specific, the length of the second partition **8** in the Z direction is equal to the distance between the first portion **61** and the second portion **62**.

The second partition **8** runs through the two or more dielectric layers constituting the main portion **21**. In the present embodiment, the second partition **8** includes a plurality of through hole lines **8**T each running through the two or more dielectric layers constituting the main portion **21**. In FIG. **1**, each through hole line **8**T is represented by a circular column. Each of the through hole lines **8**T includes two or more through holes connected in series. Each of the through hole lines **8**T extends in the Z direction. The through hole lines **8**T are arranged to be adjacent to each other in the X direction. In the present embodiment, the number of the through hole lines **8**T is five.

The connecting portion **63** of the shield **6** includes a plurality of through hole lines **63**T each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **63**T correspond to the second through hole lines in the present invention. In FIG. **1**, each through hole line **63**T is represented by a circular column. All the through hole lines represented by circular columns in FIG. **1**, except the five through hole lines **7**T and the five through hole lines **8**T, are the through hole lines **63**T. Each of the through hole lines **63**T includes two or more through holes connected in series. Each of the through hole lines **63**T extends in the Z direction.

Reference is now made to FIG. **3** to FIG. **11** to describe an example of the dielectric layers constituting the multilayer stack **20** and the configuration of a plurality of conductor layers formed on the dielectric layers and a plurality of through holes formed in the dielectric layers. In this example, the multilayer stack **20** includes eighteen dielectric layers stacked together. The eighteen dielectric layers will be referred to as the first to eighteenth dielectric layers in the order from bottom to top. The first to eighteenth dielectric layers are denoted by reference numerals **31** to **48**, respectively. The main portion **21** is composed of the first to seventeenth dielectric layers **31** to **47**. The coating portion **22** is composed of the eighteenth dielectric layer **48**. In FIG. **3** to FIG. **10**, each circle represents a through hole.

FIG. **3** illustrates a patterned surface of the first dielectric layer **31**. On the patterned surface of the first dielectric layer **31**, there are formed a conductor layer **311** forming the first input/output port **3**, a conductor layer **312** forming the second input/output port **4**, and the first conductor layer **313** forming the first portion **61** of the shield **6**.

Further, a through hole **31**T**1** connected to the conductor layer **311**, and a through hole **31**T**2** connected to the conductor layer **312** are formed in the dielectric layer **31**.

Further formed in the dielectric layer **31** are five through holes **7**T**1** constituting respective portions of the five through hole lines **7**T, five through holes **8**T**1** constituting respective portions of the five through hole lines **8**T, and a plurality of through holes **63**T**1** constituting respective portions of the plurality of through hole lines **63**T. All the through holes represented by circles in FIG. **3**, except the through holes **31**T**1**, **31**T**2**, **7**T**1** and **8**T**1**, are the through holes **63**T**1**. The through holes **7**T**1**, **8**T**1** and **63**T**1** are connected to the first conductor layer **313**.

FIG. **4** illustrates a patterned surface of the second dielectric layer **32**. Conductor layers **321** and **322** are formed on the patterned surface of the dielectric layer **32**. The through holes **31**T**1** and **31**T**2** shown in FIG. **3** are connected to the conductor layers **321** and **322**, respectively.

In the dielectric layer **32**, there are formed a through hole **32**T**1** connected to the conductor layer **321**, and a through hole **32**T**2** connected to the conductor layer **322**.

Further formed in the dielectric layer **32** are five through holes **7**T**2** constituting respective portions of the five through hole lines **7**T. The five through holes **7**T**1** shown in FIG. **3** are connected to the five through holes **7**T**2**, respectively.

Further formed in the dielectric layer **32** are five through holes **8**T**2** constituting respective portions of the five through hole lines **8**T. The five through holes **8**T**1** shown in FIG. **3** are connected to the five through holes **8**T**2**, respectively.

Further formed in the dielectric layer **32** are a plurality of through holes **63**T**2** constituting respective portions of the plurality of through hole lines **63**T. All the through holes represented by circles in FIG. **4**, except the through holes **32**T**1**, **32**T**2**, **7**T**2** and **8**T**2**, are the through holes **63**T**2**. The plurality of through holes **63**T**1** shown in FIG. **3** are connected to the plurality of through holes **63**T**2**, respectively.

FIG. **5** illustrates a patterned surface of the third dielectric layer **33**. Through holes **33**T**1** and **33**T**2** are formed in the dielectric layer **33**. The through holes **32**T**1** and **32**T**2** shown in FIG. **4** are connected to the through holes **33**T**1** and **33**T**2**, respectively.

Further formed in the dielectric layer **33** are five through holes **7**T**3** constituting respective portions of the five through hole lines **7**T. The five through holes **7**T**2** shown in FIG. **4** are connected to the five through holes **7**T**3**, respectively.

Further formed in the dielectric layer **33** are five through holes **8**T**3** constituting respective portions of the five through hole lines **8**T. The five through holes **8**T**2** shown in FIG. **4** are connected to the five through holes **8**T**3**, respectively.

Further formed in the dielectric layer **33** are a plurality of through holes **63**T**3** constituting respective portions of the plurality of through hole lines **63**T. All the through holes represented by circles in FIG. **5**, except the through holes **33**T**1**, **33**T**2**, **7**T**3** and **8**T**3**, are the through holes **63**T**3**. The plurality of through holes **63**T**2** shown in FIG. **4** are connected to the plurality of through holes **63**T**3**, respectively.

FIG. **6** illustrates a patterned surface of the fourth dielectric layer **34**. On the patterned surface of the dielectric layer **34**, there are formed a conductor layer **341** forming the line **91**, and a conductor layer **342** forming the line **92**. Each of the conductor layers **341** and **342** has a first end and a second end opposite to each other. The through hole **33**T**1** shown in FIG. **5** is connected to a portion of the conductor layer **341** near the first end thereof. The through hole **33**T**2** shown in FIG. **5** is connected to a portion of the conductor layer **342** near the first end thereof. A portion of the conductor layer **341** near the second end thereof and a portion of the conductor layer **342** near the second end thereof are opposed to the conductor layer **313** shown in FIG. **3** with the dielectric layers **31**, **32** and **33** interposed between the conductor layer **313** and each of the aforementioned portions of the conductor layers **341** and **342**.

Further formed in the dielectric layer **34** are a through hole **34**T**1** connected to the portion of the conductor layer **341** near the first end thereof, and a through hole **34**T**2** connected to the portion of the conductor layer **342** near the first end thereof.

Further formed in the dielectric layer **34** are five through holes **7**T**4** constituting respective portions of the five through hole lines **7**T. The five through holes **7**T**3** shown in FIG. **5** are connected to the five through holes **7**T**4**, respectively.

Further formed in the dielectric layer **34** are five through holes **8**T**4** constituting respective portions of the five through hole lines **8**T. The five through holes **8**T**3** shown in FIG. **5** are connected to the five through holes **8**T**4**, respectively.

Further formed in the dielectric layer **34** are a plurality of through holes **63**T**4** constituting respective portions of the plurality of through hole lines **63**T. All the through holes represented by circles in FIG. **6**, except the through holes **34**T**1**, **34**T**2**, **7**T**4** and **8**T**4**, are the through holes **63**T**4**. The plurality of through holes **63**T**3** shown in FIG. **5** are connected to the plurality of through holes **63**T**4**, respectively.

FIG. **7** illustrates a patterned surface of each of the fifth to seventh dielectric layers **35** to **37**. Through holes **35**T**1** and **35**T**2** are formed in each of the dielectric layers **35** to **37**. The through holes **34**T**1** and **34**T**2** shown in FIG. **6** are respectively connected to the through holes **35**T**1** and **35**T**2** formed in the fifth dielectric layer **35**.

In each of the dielectric layers **35** to **37**, there are further formed five through holes **7**T**5** constituting respective portions of the five through hole lines **7**T. The five through holes **7**T**4** shown in FIG. **6** are respectively connected to the five through holes **7**T**5** formed in the fifth dielectric layer **35**.

In each of the dielectric layers **35** to **37**, there are further formed five through holes **8**T**5** constituting respective portions of the five through hole lines **8**T. The five through holes **8**T**4** shown in FIG. **6** are respectively connected to the five through holes **8**T**5** formed in the fifth dielectric layer **35**.

Further, a plurality of through holes **63**T**5** constituting respective portions of the plurality of through hole lines **63**T are formed in each of the dielectric layers **35** to **37**. All the through holes represented by circles in FIG. **7**, except the through holes **35**T**1**, **35**T**2**, **7**T**5** and **8**T**5**, are the through holes **63**T**5**. The plurality of through holes **63**T**4** shown in FIG. **6** are respectively connected to the plurality of through holes **63**T**5** formed in the fifth dielectric layer **35**.

In the dielectric layers **35** to **37**, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. **8** illustrates a patterned surface of the eighth dielectric layer **38**. On the patterned surface of the dielectric layer **38**, there are formed a conductor layer **381** for forming the capacitor C**1** shown in FIG. **2** and a conductor layer **382** for forming the capacitor C**2** shown in FIG. **2**. The through hole **35**T**1** formed in the seventh dielectric layer **37** is connected to the conductor layer **381**. The through hole **35**T**2** formed in the seventh dielectric layer **37** is connected to the conductor layer **382**.

On the patterned surface of the dielectric layer **38**, there are further formed conductor layers **383**, **384**, **385** and **386** for forming the capacitors C**12**, C**23**, C**34** and C**45** shown in FIG. **2**, respectively.

Further, five through holes **7**T**8** constituting respective portions of the five through hole lines **7**T are formed in the dielectric layer **38**. The five through holes **7**T**5** formed in the seventh dielectric layer **37** are connected to the five through holes **7**T**8**, respectively.

Further formed in the dielectric layer **38** are five through holes **8**T**8** constituting respective portions of the five through hole lines **8**T. The five through holes **8**T**5** formed in the seventh dielectric layer **37** are connected to the five through holes **8**T**8**, respectively.

Further formed in the dielectric layer **38** are a plurality of through holes **63**T**8** constituting respective portions of the plurality of through hole lines **63**T. All the through holes represented by circles in FIG. **8**, except the through holes **7**T**8** and **8**T**8**, are the through holes **63**T**8**. The plurality of through holes **63**T**5** formed in the seventh dielectric layer **37** are connected to the plurality of through holes **63**T**8**, respectively.

FIG. **9** illustrates a patterned surface of the ninth dielectric layer **39**. The resonator conductor portions **510**, **520**, **530**, **540** and **550** are formed on the patterned surface of the dielectric layer **39**.

The resonator conductor portion **510** has a first end **510***a* and a second end **510***b* opposite to each other. The resonator conductor portion **520** has a first end **520***a* and a second end **520***b* opposite to each other. The resonator conductor portion **530** has a first end **530***a* and a second end **530***b* opposite to each other. The resonator conductor portion **540** has a first end **540***a* and a second end **540***b* opposite to each other. The resonator conductor portion **550** has a first end **550***a* and a second end **550***b* opposite to each other.

The resonator conductor portion **510** includes a first portion **510**A, a second portion **510**B and a third portion **510**C. The first portion **510**A includes the first end **510***a*, and the second portion **510**B includes the second end **510***b*. The first portion **510**A extends in the X direction, and the second portion **510**B extends in the Y direction. The third portion **510**C connects an end of the first portion **510**A opposite from the first end **510***a* and an end of the second portion **510**B opposite from the second end **510***b*. In FIG. **9**, the boundary between the first portion **510**A and the third portion **510**C and the boundary between the second portion **510**B and the third portion **510**C are shown by broken lines. The first portion **510**A is closer to the first input/output port **3** than the second portion **510**B in circuit configuration.

The resonator conductor portion **550** includes a first portion **550**A, a second portion **550**B and a third portion **550**C. The first portion **550**A includes the first end **550***a*, and the second portion **550**B includes the second end **550***b*. The first portion **550**A extends in the X direction, and the second portion **550**B extends in the Y direction. The third portion **550**C connects an end of the first portion **550**A opposite from the first end **550***a* and an end of the second portion **550**B opposite from the second end **550***b*. In FIG. **9**, the boundary between the first portion **550**A and the third portion **550**C and the boundary between the second portion **550**B and the third portion **550**C are shown by broken lines. The first portion **550**A is closer to the second input/output port **4** than the second portion **550**B in circuit configuration.

The second portion **510**B of the resonator conductor portion **510** and the second portion **550**B of the resonator conductor portion **550** are at a predetermined distance from each other and adjacent to each other in the X direction. The distance between the second portion **510**B and the second portion **550**B is smaller than the length of each of the resonator conductor portions **510** and **550**.

The resonator conductor portion **520** includes a first portion **520**A, a second portion **520**B and a third portion **520**C. The first portion **520**A includes the first end **520***a*, and the second portion **520**B includes the second end **520***b*. The first portion **520**A extends in the X direction, and the second portion **520**B extends in the Y direction. The third portion **520**C connects an end of the first portion **520**A opposite from the first end **520***a* and an end of the second portion **520**B opposite from the second end **520***b*. In FIG. **9**, the boundary between the first portion **520**A and the third portion **520**C and the boundary between the second portion **520**B and the third portion **520**C are shown by broken lines. The first end **520***a* is located near the second end **510***b* of the resonator conductor portion **510**.

The resonator conductor portion **540** includes a first portion **540**A, a second portion **540**B and a third portion **540**C. The first portion **540**A includes the first end **540***a*, and the second portion **540**B includes the second end **540***b*. The first portion **540**A extends in the X direction, and the second portion **540**B extends in the Y direction. The third portion **540**C connects an end of the first portion **540**A opposite from the first end **540***a* and an end of the second portion **540**B opposite from the second end **540***b*. In FIG. **9**, the boundary between the first portion **540**A and the third portion **540**C and the boundary between the second portion **540**B and the third portion **540**C are shown by broken lines. The first end **540***a* is located near the second end **550***b* of the resonator conductor portion **550**.

The first end **520***a* of the resonator conductor portion **520** and the first end **540***a* of the resonator conductor portion **540** are at a predetermined distance from each other and adjacent to each other. The distance between the first end **520***a* and the first end **540***a* is sufficiently smaller than the length of each of the resonator conductor portions **520** and **540**.

The resonator conductor portion **530** extends in the X direction. The first end **530***a* of the resonator conductor portion **530** is located near the second end **520***b* of the resonator conductor portion **520**. The second end **530***b* of the resonator conductor portion **530** is located near the second end **540***b* of the resonator conductor portion **540**. Further, five through holes **7**T**9** constituting respective portions of the five through hole lines **7**T are formed in the dielectric layer **39**. The five through holes **7**T**8** shown in FIG. **8** are connected to the five through holes **7**T**9**, respectively.

Further formed in the dielectric layer **39** are five through holes **8**T**9** constituting respective portions of the five through hole lines **8**T. The five through holes **8**T**8** shown in FIG. **8** are connected to the five through holes **8**T**9**, respectively.

Further formed in the dielectric layer **39** are a plurality of through holes **63**T**9** constituting respective portions of the plurality of through hole lines **63**T. All the through holes represented by circles in FIG. **9**, except the through holes **7**T**9** and **8**T**9**, are the through holes **63**T**9**. The plurality of through holes **63**T**8** shown in FIG. **8** are connected to the plurality of through holes **63**T**9**, respectively.

FIG. **10** illustrates a patterned surface of each of the tenth to seventeenth dielectric layers **40** to **47**. Five through holes **7**T**10** constituting respective portions of the five through hole lines **7**T are formed in each of the dielectric layers **40** to **47**. The five through holes **7**T**9** shown in FIG. **9** are respectively connected to the five through holes **7**T**10** formed in the tenth dielectric layer **40**.

In each of the dielectric layers **40** to **47**, there are further formed five through holes **8**T**10** constituting respective portions of the five through hole lines **8**T. The five through holes **8**T**9** shown in FIG. **9** are respectively connected to the five through holes **8**T**10** formed in the tenth dielectric layer **40**.

Further, a plurality of through holes **63**T**10** constituting respective portions of the plurality of through hole lines **63**T are formed in each of the dielectric layers **40** to **47**. All the through holes represented by circles in FIG. **10**, except the through holes **7**T**10** and **8**T**10**, are the through holes **63**T**10**. The plurality of through holes **63**T**9** shown in FIG. **9** are respectively connected to the plurality of through holes **63**T**10** formed in the tenth dielectric layer **40**.

In the dielectric layers **40** to **47**, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. **11** illustrates a patterned surface of the eighteenth dielectric layer **48**. The second conductor layer **481** forming the second portion **62** of the shield **6** is formed on the patterned surface of the dielectric layer **48**. The through holes **7**T**10**, **8**T**10** and **63**T**10** formed in the seventeenth dielectric layer **47** are connected to the second conductor layer **481**.

The band-pass filter **1** according to the present embodiment is formed by stacking the first to eighteenth dielectric layers **31** to **48** such that the patterned surface of the first dielectric layer **31** also serves as the first end face **2**A of the main body **2**. A surface of the eighteenth dielectric layer **48** opposite to the patterned surface serves as the second end face **2**B of the main body **2**. The first to eighteenth dielectric layers **31** to **48** constitute the multilayer stack **20**.

The respective resonator conductor portions **510**, **520**, **530**, **540** and **550** of the resonators **51** to **55** are located at the same position in the multilayer stack **20** in the first direction, i.e., the Z direction.

The conductor layer **311** forming the first input/output port **3** is connected to the conductor layer **381** shown in FIG. **8** via the through hole **31**T**1**, the conductor layer **321** and the through holes **32**T**1**, **33**T**1**, **34**T**1** and **35**T**1**. The conductor layer **381** is opposed to a portion of the resonator conductor portion **510** (FIG. **9**) near the first end **510***a* with the dielectric layer **38** interposed therebetween. The capacitor C**1** shown in FIG. **2** is composed of the conductor layer **381** and the resonator conductor portion **510**, and also the dielectric layer **38** interposed therebetween.

The conductor layer **312** forming the second input/output port **4** is connected to the conductor layer **382** shown in FIG. **8** via the through hole **31**T**2**, the conductor layer **322** and the through holes **32**T**2**, **33**T**2**, **34**T**2** and **35**T**2**. The conductor layer **382** is opposed to a portion of the resonator conductor portion **550** (FIG. **9**) near the first end **550***a* with the dielectric layer **38** interposed therebetween. The capacitor C**2** shown in FIG. **2** is composed of the conductor layer **382** and the resonator conductor portion **550**, and also the dielectric layer **38** interposed therebetween.

The conductor layer **383** shown in FIG. **8** is opposed to a portion of the resonator conductor portion **510** near the second end **510***b* and to a portion of the resonator conductor portion **520** near the first end **520***a*, with the dielectric layer **38** interposed between the conductor layer **383** and each of the aforementioned respective portions of the resonator conductor portions **510** and **520**. The capacitor C**12** shown in FIG. **2** is composed of the conductor layer **383**, the resonator conductor portions **510** and **520**, and the dielectric layer **38** interposed between the conductor layer **383** and the resonator conductor portions **510** and **520**.

The conductor layer **384** shown in FIG. **8** is opposed to a portion of the resonator conductor portion **520** near the second end **520***b* and to a portion of the resonator conductor portion **530** near the first end **530***a*, with the dielectric layer **38** interposed between the conductor layer **384** and each of the aforementioned respective portions of the resonator conductor portions **520** and **530**. The capacitor C**23** shown in FIG. **2** is composed of the conductor layer **384**, the resonator conductor portions **520** and **530**, and the dielectric layer **38** interposed between the conductor layer **384** and the resonator conductor portions **520** and **530**.

The conductor layer **385** shown in FIG. **8** is opposed to a portion of the resonator conductor portion **530** near the second end **530***b* and to a portion of the resonator conductor portion **540** near the second end **540***b*, with the dielectric layer **38** interposed between the conductor layer **385** and each of the aforementioned respective portions of the resonator conductor portions **530** and **540**. The capacitor C**34** shown in FIG. **2** is composed of the conductor layer **385**, the resonator conductor portions **530** and **540**, and the dielectric layer **38** interposed between the conductor layer **385** and the resonator conductor portions **530** and **540**.

The conductor layer **386** shown in FIG. **8** is opposed to a portion of the resonator conductor portion **540** near the first end **540***a* and to a portion of the resonator conductor portion **550** near the second end **550***b*, with the dielectric layer **38** interposed between the conductor layer **386** and each of the aforementioned respective portions of the resonator conductor portions **540** and **550**. The capacitor C**45** shown in FIG. **2** is composed of the conductor layer **386**, the resonator conductor portions **540** and **550**, and the dielectric layer **38** interposed between the conductor layer **386** and the resonator conductor portions **540** and **550**.

Each of the five through hole lines **7**T of the first partition **7** is formed by connecting the through holes **7**T**1**, **7**T**2**, **7**T**3**, **7**T**4**, **7**T**5**, **7**T**8**, **7**T**9** and **7**T**10** in series in the Z direction.

In the example shown in FIG. **3** to FIG. **11**, part of the first partition **7** extends to pass between the second portion **510**B of the resonator conductor portion **510** and the second portion **550**B of the resonator conductor portion **550**, and is in contact with the first portion **61** and the second portion **62**.

Each of the five through hole lines **8**T of the second partition **8** is formed by connecting the through holes **8**T**1**, **8**T**2**, **8**T**3**, **8**T**4**, **8**T**5**, **8**T**8**, **8**T**9** and **8**T**10** in series in the Z direction.

Each of the plurality of through hole lines **63**T of the connecting portion **63** is formed by connecting the through holes **63**T**1**, **63**T**2**, **63**T**3**, **63**T**4**, **63**T**5**, **63**T**8**, **63**T**9** and **63**T**10** in series in the Z direction.

In the present embodiment, the resonators **51** and **55** which are not adjacent to each other in circuit configuration are magnetically coupled to each other, while the resonators **52** and **54** which are not adjacent to each other in circuit configuration are capacitively coupled to each other. The resonator **51** and the resonator **52** are adjacent to each other in circuit configuration and are also capacitively coupled to each other. The resonator **55** and the resonator **54** are adjacent to each other in circuit configuration and are also capacitively coupled to each other. The resonator conductor portions **510**, **520**, **540**, and **550** of the resonators **51**, **52**, **54**, and **55** having such relationships in circuit configuration have the following physical relationships with each other.

The resonator conductor portion **510** of the resonator **51** and the resonator conductor portion **550** of the resonator **55** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. In the present embodiment, in particular, the second portion **510**B of the resonator conductor portion **510** and the second portion **550**B of the resonator conductor portion **550**, both of which extend in the Y direction, are physically adjacent to each other in the X direction without any resonator conductor portion of another resonator therebetween. The magnetic coupling between the resonators **51** and **55** is thereby achieved.

The resonator conductor portion **520** of the resonator **52** and the resonator conductor portion **540** of the resonator **54** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. In the present embodiment, in particular, the first end **520***a* of the resonator conductor portion **520** and the first end **540***a* of the resonator conductor portion **540** are at a small distance from each other and adjacent to each other, without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **52** and **54** is thereby achieved.

The resonator conductor portion **510** of the resonator **51** and the resonator conductor portion **520** of the resonator **52** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **51** and **52** is thereby achieved easily.

The resonator conductor portion **540** of the resonator **54** and the resonator conductor portion **550** of the resonator **55** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **54** and **55** is thereby achieved easily.

The function and effects of the band-pass filter **1** according to the present embodiment will now be described. For example, the band-pass filter **1** is designed and configured to have a passband in a quasi-millimeter wave band of 10 to 30 GHz or a millimeter wave band of 30 to 300 GHz.

The band-pass filter **1** includes the resonators **51**, **52**, **53**, **54** and **55** which are provided between the first input/output port **3** and the second input/output port **4** and arranged in the listed order, from closest to farthest from the first input/output port **3**. The resonators **51** to **55** are configured so that electromagnetic coupling, more specifically, capacitive coupling, is established between every two of the resonators adjacent to each other in circuit configuration.

The band-pass filter **1** includes the shield **6**. The shield **6** has the function of preventing electromagnetic radiation to the surroundings of the band-pass filter **1**. In the present embodiment, the shield **6** and the dielectric inside the shield **6** constitute a structure similar to a waveguide, thereby generating one or more waveguide modes. The one or more waveguide modes usually have resonance frequencies in a frequency region higher than the passband of the band-pass filter **1**. If one of the waveguide modes that is the lowest in resonance frequency, i.e., the lowest-order waveguide mode, has a resonance frequency relatively close to the passband of the band-pass filter **1**, there occurs the problem that the attenuation characteristic in the frequency region above the passband deteriorates due to unwanted resonance at the resonance frequency of the lowest-order waveguide mode.

The band-pass filter **1** according to the present embodiment prevents the occurrence of the foregoing problem by the provision of the first and second partitions **7** and **8**. This will be described in detail below. Assuming that there are no partitions **7** and **8**, the resonance frequency of the lowest-order waveguide mode depends on the shape of the space defined by the shield **6**. Typically, the larger the space, the lower the resonance frequency of the lowest-order waveguide mode.

In the present embodiment, the first and second partitions **7** and **8** divide the space defined by the shield **6** into a plurality of spaces. Specifically, in the present embodiment, the first partition **7** divides the space defined by the shield **6** into a space in which the resonator conductor portion **510** is located and a space in which the resonator conductor portion **550** is located.

In the present embodiment, the resonance frequency of the lowest-order waveguide mode depends on the shape of each of the plurality of spaces divided by the first and second partitions **7** and **8**. Each of these plurality of spaces is smaller than the space defined by the shield **6** in the absence of the partitions **7** and **8**. The present invention thus makes the resonance frequency of the lowest-order waveguide mode higher than in the case where there are no partitions **7** and **8**. Consequently, the band-pass filter **1** according to the present embodiment prevents the attenuation characteristic in the frequency region above the passband from being degraded by the lowest-order waveguide mode.

In the present embodiment, the first stage resonator **51** and the fifth stage resonator **55**, which are not adjacent to each other in circuit configuration, are magnetically coupled to each other. This enables creation of an attenuation pole in at least one of two frequency regions in a frequency response of insertion loss. One of the two frequency regions is a first passband-vicinity region, which is a frequency region close to the passband and lower than the passband, and the other is a second passband-vicinity region, which is a frequency region close to the passband and higher than the passband. Note that the passband is, for example, a frequency band between two frequencies at which the insertion loss becomes higher by 3 dB than its minimum value.

In the present embodiment, specifically, the magnetic coupling between the first stage resonator **51** and the fifth stage resonator **55** creates an attenuation pole in the first passband-vicinity region.

In the present embodiment, the second stage resonator **52** and the fourth stage resonator **54**, which are not adjacent to each other in circuit configuration, are capacitively coupled to each other. This enables creation of an attenuation pole in the second passband-vicinity region.

By virtue of these features, the present embodiment provides the band-pass filter **1** which includes the five resonators **51** and **55** and the shield **6** and has favorable characteristics. In the present embodiment, the favorable characteristics of the band-pass filter **1** specifically refer to steep changes in the insertion loss in both of the first and second passband-vicinity regions, and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

In the present embodiment, at least part of the first partition **7** extends to pass between the resonator conductor portion **510** and the resonator conductor portion **550**. The resonator conductor portion **510** and the resonator conductor portion **550** respectively constitute the resonator **51** and the resonator **55**, which are magnetically coupled to each other although not adjacent to each other in circuit configuration. The magnetic coupling between the resonators **51** and **55** can be weaker than the electromagnetic coupling between any two resonators that are adjacent to each other in circuit configuration. According to the present embodiment, it is thus possible to establish magnetic coupling between the resonators **51** and **55** while disposing the first partition **7** such that at least part thereof passes between the resonator conductor portion **510** and the resonator conductor portion **550**. The present embodiment thus achieves both of prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode by the provision of the first partition **7** and the creation of an attenuation pole by establishing magnetic coupling between the resonators **51** and **55**. This results in the favorable characteristics of the band-pass filter **1**.

Each of the five resonators **51** to **55** in the present embodiment is a half-wave resonator. In this case, each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** may have a harmonic resonance mode in addition to a basic resonance mode, the basic resonance mode having a basic resonance frequency which determines the passband, the harmonic resonance mode having a resonance frequency twice as high as the basic resonance frequency. The harmonic resonance mode may degrade the attenuation characteristic in a frequency region above the passband.

To address this problem, the band-pass filter **1** according to the present embodiment has the notch filter section capable of attenuating signals having a resonance frequency twice as high as the basic resonance frequency. The present embodiment thereby prevents the attenuation characteristic from being degraded by the harmonic resonance mode.

In the present embodiment, the resonator conductor portions **510**, **520**, **540** and **550** of the resonators **51**, **52**, **54** and **55** having the above-described relationship in circuit configuration are configured to have the above-described physical relationship. The present embodiment thus realizes the band-pass filter **1** which has two cross couplings and is simple in structure.

Now, an example of characteristics of the band-pass filter **1** according to the present embodiment and an example of characteristics of a band-pass filter of a first comparative example will be discussed. The band-pass filter of the first comparative example has the same configuration as that of the band-pass filter **1** except that the first partition **7** is omitted.

FIG. **12** illustrates an example frequency response of the insertion loss of the band-pass filter **1** according to the present embodiment. FIG. **13** illustrates an example frequency response of the insertion loss of the band-pass filter of the first comparative example. The frequency responses shown in FIGS. **12** and **13** were obtained by simulation. In FIGS. **12** and **13**, the horizontal axis represents frequency, and the vertical axis represents insertion loss. In the examples shown in FIGS. **12** and **13**, the band-pass filter **1** and the band-pass filter of the first comparative example have a passband of approximately 26 to 30 GHz, and the center frequency of the passband is approximately 28 GHz.

For the band-pass filter **1** used in the simulation, the magnitudes of the two cross couplings were adjusted, based on the presence of the first partition **7**, so as to create attenuation poles in both of the first passband-vicinity region and the second passband-vicinity region, as shown in FIG. **12**. The first passband-vicinity region is a frequency region of approximately 24 to 26 GHz. The second passband-vicinity region is a frequency region of approximately 30 to 32 GHz. As illustrated in FIG. **13**, the characteristic of the band-pass filter of the first comparative example shows no attenuation pole in the first passband-vicinity region, and shows a lower insertion loss than that of the band-pass filter **1** at an attenuation pole in the second passband-vicinity region. This is because, for the band-pass filter of the first comparative example, the omission of the first partition **7** resulted in a deviation of the magnitude of the magnetic coupling between the resonators **51** and **55** from the adjusted magnitude in the band-pass filter **1**.

Further, the characteristic of the band-pass filter of the first comparative example shown in FIG. **13** exhibits a peak of an extreme reduction in the insertion loss at approximately 40 GHz. This is considered to be due to unwanted resonance caused by the lowest-order waveguide mode at approximately 40 GHz. In contrast, the characteristic of the band-pass filter **1** shown in FIG. **12** exhibits no such peak as that occurring in the characteristic shown in FIG. **13**, and thus exhibits a better attenuation characteristic in a frequency region above the passband, when compared with the characteristic shown in FIG. **13**.

Further, the characteristic of the band-pass filter **1** shown in FIG. **12** exhibits an increase in the insertion loss at approximately 55 GHz. This is due to the effect of the notch filter section.

It is apparent from FIG. **12** that the band-pass filter **1** according to the present embodiment provides the favorable characteristics achieving steep changes in the insertion loss in both of the first and second passband-vicinity regions and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

Second Embodiment

A second embodiment of the present invention will now be described. First, the configuration of a band-pass filter according to the present embodiment will be described with reference to FIG. **14** and FIG. **15**. FIG. **14** is a perspective view illustrating the structure of the band-pass filter according to the second embodiment. FIG. **15** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the second embodiment.

The band-pass filter **100** according to the present embodiment includes the main body **2**, the first input/output port **3**, the second input/output port **4**, three or more resonators, the shield **6**, a partition **107**, and a coupling adjustment section **108**. The main body **2** includes the multilayer stack **20**.

The three or more resonators are located between the first input/output port **3** and the second input/output port **4** in circuit configuration. In the present embodiment, the three or more resonators are six resonators **151**, **152**, **153**, **154**, **155** and **156**. The six resonators **151**, **152**, **153**, **154**, **155** and **156** are arranged in this order, from closest to farthest, from the first input/output port **3** in circuit configuration. The six resonators **151** to **156** are configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. Specifically, the resonators **151** to **156** are configured so that the resonators **151** and **152** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators **152** and **153** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators **153** and **154** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators **154** and **155** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, and the resonators **155** and **156** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other. In the present embodiment, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is specifically capacitive coupling. In the present embodiment, each of the resonators **151** to **156** is a resonator with open ends, and also a half-wave resonator.

The first portion **61**, the second portion **62** and the connecting portion **63** of the shield **6** are arranged to surround the six resonators **151** to **156**. The first portion **61** is formed of a first conductor layer **1313** disposed on the first end face **21***a* of the main portion **21** of the multilayer stack **20**. The second portion **62** is formed of a second conductor layer **1521** disposed on the second end face **21***b* of the main portion **21** of the multilayer stack **20**.

The band-pass filter **100** includes a capacitor C**112** for establishing capacitive coupling between the resonators **151** and **152**, a capacitor C**123** for establishing capacitive coupling between the resonators **152** and **153**, a capacitor C**134** for establishing capacitive coupling between the resonators **153** and **154**, a capacitor C**145** for establishing capacitive coupling between the resonators **154** and **155**, and a capacitor C**156** for establishing capacitive coupling between the resonators **155** and **156**.

In the present embodiment, among the six resonators **151** to **156**, the resonator **152**, which is the second closest to the first input/output port **3** in circuit configuration, and the resonator **155**, which is the second closest to the second input/output port **4** in circuit configuration, are magnetically coupled to each other although they are not adjacent to each other in circuit configuration. The resonator **152** corresponds to the first resonator in the present invention. The resonator **155** corresponds to the second resonator in the present invention.

Further, in the present embodiment, among the six resonators **151** to **156**, the resonator **151**, which is the closest to the first input/output port **3** in circuit configuration, and the resonator **156**, which is the closest to the second input/output port **4** in circuit configuration, are capacitively coupled to each other although they are not adjacent to each other in circuit configuration. In FIG. **15**, the capacitor symbol C**116** represents the capacitive coupling between the resonators **151** and **156**.

The band-pass filter **100** further includes a capacitor C**101** provided between the first input/output port **3** and the resonator **151**, and a capacitor C**102** provided between the second input/output port **4** and the resonator **156**.

The band-pass filter **100** further includes the two lines **91** and **92** as in the first embodiment.

The resonator **151** includes a resonator conductor portion **1510** formed of a conductor. The resonator **152** includes a resonator conductor portion **1520** formed of a conductor. The resonator **153** includes a resonator conductor portion **1530** formed of a conductor. The resonator **154** includes a resonator conductor portion **1540** formed of a conductor. The resonator **155** includes a resonator conductor portion **1550** formed of a conductor. The resonator **156** includes a resonator conductor portion **1560** formed of a conductor. The resonator conductor portion **1520** corresponds to the first resonator conductor portion in the present invention. The resonator conductor portion **1550** corresponds to the second resonator conductor portion in the present invention.

Each of the resonator conductor portions **1510**, **1520**, **1530**, **1540**, **1550** and **1560** extends in a direction intersecting the first direction or the Z direction. In the present embodiment, specifically, each of the resonator conductor portions **1510**, **1520**, **1530**, **1540**, **1550** and **1560** extends in a direction orthogonal to the first direction or the Z direction.

Each of the resonator conductor portions **1510**, **1520**, **1530**, **1540**, **1550** and **1560** has a first end and a second end opposite to each other. As mentioned above, each of the resonators **151** to **156** is a resonator with open ends. Thus, both of the first and second ends of each of the resonator conductor portions **1510**, **1520**, **1530**, **1540**, **1550** and **1560** are open. Each of the resonator conductor portions **1510**, **1520**, **1530**, **1540**, **1550** and **1560** has a length of one half or nearly one half the wavelength corresponding to the center frequency of the passband of the band-pass filter **100**.

The partition **107** is in contact with the first portion **61** and the second portion **62**. At least part of the partition **107** extends to pass between the resonator conductor portion **1520** and the resonator conductor portion **1550**. In the present embodiment, specifically, the partition **107** extends in the first direction, i.e., the Z direction. The partition **107** connects the first portion **61** and the second portion **62** via the shortest path. To be more specific, the length of the partition **107** in the Z direction is equal to the distance between the first portion **61** and the second portion **62**.

The partition **107** runs through the two or more dielectric layers constituting the main portion **21**. In the present embodiment, the partition **107** includes a plurality of through hole lines **107**T each running through the two or more dielectric layers constituting the main portion **21**, and includes a conductor layer **107**C. The plurality of through hole lines **107**T correspond to the plurality of first through hole lines in the present invention. In FIG. **14**, each through hole line **107**T is represented by a circular column. Each of the through hole lines **107**T includes two or more through holes connected in series. Each of the through hole lines **107**T extends in the Z direction. The through hole lines **107**T are arranged to be adjacent to each other in the Y direction. In the present embodiment, the number of the through hole lines **107**T is seven.

The coupling adjustment section **108** is intended to adjust the magnitude of the capacitive coupling between the resonators **151** and **156**. The coupling adjustment section **108** includes a plurality of through hole lines **108**T each running through the two or more dielectric layers constituting the main portion **21**. In FIG. **14**, each through hole line **108**T is represented by a circular column. Each of the through hole lines **108**T includes two or more through holes connected in series. Each of the through hole lines **108**T extends in the Z direction and is in contact with the first portion **61** and the second portion **62**. The through hole lines **108**T are arranged to be adjacent to each other in the Y direction in the vicinity of the second end of the resonator conductor portion **1510** and the second end of the resonator conductor portion **1560**. In the present embodiment, the number of the through hole lines **108**T is two.

The connecting portion **63** of the shield **6** includes a plurality of through hole lines **163**T each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **163**T correspond to the second through hole lines in the present invention. In FIG. **14**, each through hole line **163**T is represented by a circular column. All the through hole lines represented by circular columns in FIG. **14**, except the seven through hole lines **107**T and the two through hole lines **108**T, are the through hole lines **163**T. Each of the through hole lines **163**T includes two or more through holes connected in series. Each of the through hole lines **163**T extends in the Z direction.

Reference is now made to FIG. **16** to FIG. **24** to describe an example of a plurality of dielectric layers constituting the multilayer stack **20** and the configuration of a plurality of conductor layers formed on the dielectric layers and a plurality of through holes formed in the dielectric layers. In this example, the multilayer stack **20** includes twenty-two dielectric layers stacked together. The twenty-two dielectric layers will be referred to as the first to twenty-second dielectric layers in the order from bottom to top. The first to twenty-second dielectric layers are denoted by reference numerals **131** to **152**, respectively. The main portion **21** is composed of the first to twenty-first dielectric layers **131** to **151**. The coating portion **22** is composed of the twenty-second dielectric layer **152**. In FIG. **16** to FIG. **23**, each circle represents a through hole.

FIG. **16** illustrates a patterned surface of the first dielectric layer **131**. On the patterned surface of the first dielectric layer **131**, there are formed a conductor layer **1311** forming the first input/output port **3**, a conductor layer **1312** forming the second input/output port **4**, and the first conductor layer **1313** forming the first portion **61** of the shield **6**.

Further, a through hole **131**T**1** connected to the conductor layer **1311**, and a through hole **131**T**2** connected to the conductor layer **1312** are formed in the dielectric layer **131**. Further formed in the dielectric layer **131** are seven through holes **107**T**1** constituting respective portions of the seven through hole lines **107**T, two through holes **108**T**1** constituting respective portions of the two through hole lines **108**T, and a plurality of through holes **163**T**1** constituting respective portions of the plurality of through hole lines **163**T. All the through holes represented by circles in FIG. **16**, except the through holes **131**T**1**, **131**T**2**, **107**T**1** and **108**T**1**, are the through holes **163**T**1**. The through holes **107**T**1**, **108**T**1** and **163**T**1** are connected to the first conductor layer **1313**.

FIG. **17** illustrates a patterned surface of each of the second and third dielectric layers **132** and **133**. Through holes **132**T**1** and **132**T**2** are formed in each of the dielectric layers **132** and **133**. The through holes **131**T**1** and **131**T**2** shown in FIG. **16** are connected to the through holes **132**T**1** and **132**T**2**, respectively.

In each of the dielectric layers **132** and **133**, there are further formed seven through holes **107**T**2** constituting respective portions of the seven through hole lines **107**T. The seven through holes **107**T**1** shown in FIG. **16** are respectively connected to the seven through holes **107**T**2** formed in the second dielectric layer **132**.

In each of the dielectric layers **132** and **133**, there are further formed two through holes **108**T**2** constituting respective portions of the two through hole lines **108**T. The two through holes **108**T**1** shown in FIG. **16** are respectively connected to the two through holes **108**T**2** formed in the second dielectric layer **132**.

Further, a plurality of through holes **163**T**2** constituting respective portions of the plurality of through hole lines **163**T are formed in each of the dielectric layers **132** and **133**. All the through holes represented by circles in FIG. **17**, except the through holes **132**T**1**, **132**T**2**, **107**T**2** and **108**T**2**, are the through holes **163**T**2**. The plurality of through holes **163**T**1** shown in FIG. **16** are respectively connected to the plurality of through holes **163**T**2** formed in the second dielectric layer **132**.

In the dielectric layers **132** and **133**, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. **18** illustrates a patterned surface of the fourth dielectric layer **134**. On the patterned surface of the dielectric layer **134**, there are formed a conductor layer **1341** forming the line **91** and a conductor layer **1342** forming the line **92**. Each of the conductor layers **1341** and **1342** has a first end and a second end opposite to each other. The through hole **132**T**1** formed in the third dielectric layer **133** is connected to a portion of the conductor layer **1341** near the first end thereof. The through hole **132**T**2** formed in the third dielectric layer **133** is connected to a portion of the conductor layer **1342** near the first end thereof. A portion of the conductor layer **1341** near the second end thereof and a portion of the conductor layer **1342** near the second end thereof are opposed to the conductor layer **1313** shown in FIG. **16** with the dielectric layers **131**, **132** and **133** interposed between the conductor layer **1313** and each of the aforementioned portions of the conductor layers **1341** and **1342**.

Further formed in the dielectric layer **134** are a through hole **134**T**1** connected to the portion of the conductor layer **1341** near the first end thereof, and a through hole **134**T**2** connected to the portion of the conductor layer **1342** near the first end thereof.

Further, seven through holes **107**T**4** constituting respective portions of the seven through hole lines **107**T are formed in the dielectric layer **134**. The seven through holes **107**T**2** formed in the third dielectric layer **133** are connected to the seven through holes **107**T**4**, respectively.

Further formed in the dielectric layer **134** are two through holes **108**T**4** constituting respective portions of the two through hole lines **108**T. The two through holes **108**T**2** formed in the third dielectric layer **133** are connected to the two through holes **108**T**4**, respectively.

Further formed in the dielectric layer **134** are a plurality of through holes **163**T**4** constituting respective portions of the plurality of through hole lines **163**T. All the through holes represented by circles in FIG. **18**, except the through holes **134**T**1**, **134**T**2**, **107**T**4** and **108**T**4**, are the through holes **163**T**4**. The plurality of through holes **163**T**2** formed in the third dielectric layer **133** are connected to the plurality of through holes **163**T**4**, respectively.

FIG. **19** illustrates a patterned surface of each of the fifth to ninth dielectric layers **135** to **139**. Through holes **135**T**1** and **135**T**2** are formed in each of the dielectric layers **135** to **139**. The through holes **134**T**1** and **134**T**2** shown in FIG. **18** are respectively connected to the through holes **135**T**1** and **135**T**2** formed in the fifth dielectric layer **135**.

In each of the dielectric layers **135** to **139**, there are further formed seven through holes **107**T**5** constituting respective portions of the seven through hole lines **107**T. The seven through holes **107**T**4** shown in FIG. **18** are respectively connected to the seven through holes **107**T**5** formed in the fifth dielectric layer **135**.

In each of the dielectric layers **135** to **139**, there are further formed two through holes **108**T**5** constituting respective portions of the two through hole lines **108**T. The two through holes **108**T**4** shown in FIG. **18** are respectively connected to the two through holes **108**T**5** formed in the fifth dielectric layer **135**.

Further, a plurality of through holes **163**T**5** constituting respective portions of the plurality of through hole lines **163**T are formed in each of the dielectric layers **135** to **139**. All the through holes represented by circles in FIG. **19**, except the through holes **135**T**1**, **135**T**2**, **107**T**5** and **108**T**5**, are the through holes **163**T**5**. The plurality of through holes **163**T**4** shown in FIG. **18** are respectively connected to the plurality of through holes **163**T**5** formed in the fifth dielectric layer **135**.

In the dielectric layers **135** to **139**, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. **20** illustrates a patterned surface of the tenth dielectric layer **140**. On the patterned surface of the dielectric layer **140**, there are formed a conductor layer **1401** for forming the capacitor C**101** shown in FIG. **15** and a conductor layer **1402** for forming the capacitor C**102** shown in FIG. **15**. The through hole **135**T**1** formed in the ninth dielectric layer **139** is connected to the conductor layer **1401**. The through hole **135**T**2** formed in the ninth dielectric layer **139** is connected to the conductor layer **1402**.

On the patterned surface of the dielectric layer **140**, there are further formed conductor layers **1403**, **1404**, **1405**, **1406** and **1407** for forming the capacitors C**112**, C**123**, C**134**, C**145** and C**156** shown in FIG. **15**, respectively.

Further, seven through holes **107**T**10** constituting respective portions of the seven through hole lines **107**T are formed in the dielectric layer **140**. The seven through holes **107**T**5** formed in the ninth dielectric layer **139** are connected to the seven through holes **107**T**10**, respectively.

Further formed in the dielectric layer **140** are two through holes **108**T**10** constituting respective portions of the two through hole lines **108**T. The two through holes **108**T**5** formed in the ninth dielectric layer **139** are connected to the two through holes **108**T**10**, respectively.

Further formed in the dielectric layer **140** are a plurality of through holes **163**T**10** constituting respective portions of the plurality of through hole lines **163**T. All the through holes represented by circles in FIG. **20**, except the through holes **107**T**10** and **108**T**10**, are the through holes **163**T**10**. The plurality of through holes **163**T**5** formed in the ninth dielectric layer **139** are connected to the plurality of through holes **163**T**10**, respectively.

FIG. **21** illustrates a patterned surface of the eleventh dielectric layer **141**. In the dielectric layer **141**, there are formed seven through holes **107**T**11** constituting respective portions of the seven through hole lines **107**T. The seven through holes **107**T**10** shown in FIG. **20** are connected to the seven through holes **107**T**11**, respectively.

Further formed in the dielectric layer **141** are two through holes **108**T**11** constituting respective portions of the two through hole lines **108**T. The two through holes **108**T**10** shown in FIG. **20** are connected to the two through holes **108**T**11**, respectively.

Further formed in the dielectric layer **141** are a plurality of through holes **163**T**11** constituting respective portions of the plurality of through hole lines **163**T. All the through holes represented by circles in FIG. **21**, except the through holes **107**T**11** and **108**T**11**, are the through holes **163**T**11**. The plurality of through holes **163**T**10** shown in FIG. **20** are connected to the plurality of through holes **163**T**11**, respectively.

FIG. **22** illustrates a patterned surface of the twelfth dielectric layer **142**. The resonator conductor portions **1510**, **1520**, **1530**, **1540**, **1550** and **1560** are formed on the patterned surface of the dielectric layer **142**.

The resonator conductor portion **1510** has a first end **1510***a* and a second end **1510***b* opposite to each other. The resonator conductor portion **1520** has a first end **1520***a* and a second end **1520***b* opposite to each other. The resonator conductor portion **1530** has a first end **1530***a* and a second end **1530***b* opposite to each other. The resonator conductor portion **1540** has a first end **1540***a* and a second end **1540***b* opposite to each other. The resonator conductor portion **1550** has a first end **1550***a* and a second end **1550***b* opposite to each other. The resonator conductor portion **1560** has a first end **1560***a* and a second end **1560***b* opposite to each other.

Each of the resonator conductor portions **1510** and **1560** extends in the X direction. The resonator conductor portions **1510** and **1560** are arranged in such a positional relationship that one straight line extends across the resonator conductor portions **1510** and **1560** in the X direction. The second end **1510***b* of the resonator conductor portion **1510** and the second end **1560***b* of the resonator conductor portion **1560** are at a predetermined distance from each other and adjacent to each other. The distance between the second end **1510***b* and the second end **1560***b* is sufficiently smaller than the length of each of the resonator conductor portions **1510** and **1560**.

Each of the resonator conductor portions **1520** and **1550** extends in the Y direction. The resonator conductor portions **1520** and **1550** are at a predetermined distance from each other and adjacent to each other in the X direction. The distance between the resonator conductor portions **1520** and **1550** is smaller than the length of each of the resonator conductor portions **1520** and **1550**.

The first end **1520***a* of the resonator conductor portion **1520** is located near the second end **1510***b* of the resonator conductor portion **1510**. The first end **1550***a* of the resonator conductor portion **1550** is located near the second end **1560***b* of the resonator conductor portion **1560**.

The resonator conductor portion **1530** includes a first portion **1530**A, a second portion **1530**B and a third portion **1530**C. The first portion **1530**A includes the first end **1530***a*, and the second portion **1530**B includes the second end **1530***b*. The first portion **1530**A extends in the X direction, and the second portion **1530**B extends in the Y direction. The third portion **1530**C connects an end of the first portion **1530**A opposite from the first end **1530***a* and an end of the second portion **1530**B opposite from the second end **1530***b*. In FIG. **22**, the boundary between the first portion **1530**A and the third portion **1530**C and the boundary between the second portion **1530**B and the third portion **1530**C are shown by broken lines. The first end **1530***a* is located near the second end **1520***b* of the resonator conductor portion **1520**.

The resonator conductor portion **1540** includes a first portion **1540**A, a second portion **1540**B and a third portion

1540C. The first portion **1540**A includes the first end **1540***a*, and the second portion **1540**B includes the second end **1540***b*. The first portion **1540**A extends in the X direction, and the second portion **1540**B extends in the Y direction. The third portion **1540**C connects an end of the first portion **1540**A opposite from the first end **1540***a* and an end of the second portion **1540**B opposite from the second end **1540***b*. In FIG. **22**, the boundary between the first portion **1540**A and the third portion **1540**C and the boundary between the second portion **1540**B and the third portion **1540**C are shown by broken lines. The first end **1540***a* is located near the second end **1550***b* of the resonator conductor portion **1550**.

The first end **1530***a* of the resonator conductor portion **1530** and the first end **1540***a* of the resonator conductor portion **1540** are at a predetermined distance from each other and adjacent to each other.

The conductor layer **107**C constituting part of the partition **107** is further formed on the patterned surface of the dielectric layer **142**. The conductor layer **107**C is situated between the resonator conductor portion **1520** and the resonator conductor portion **1550**, and extends in the Y direction.

Further, seven through holes **107**T**12** constituting respective portions of the seven through hole lines **107**T are formed in the dielectric layer **142**. The seven through holes **107**T**12** are connected to the conductor layer **107**C. The seven through holes **107**T**11** shown in FIG. **21** are connected to the seven through holes **107**T**12**, respectively.

Further formed in the dielectric layer **142** are two through holes **108**T**12** constituting respective portions of the two through hole lines **108**T. The two through holes **108**T**11** shown in FIG. **21** are connected to the two through holes **108**T**12**, respectively.

Further formed in the dielectric layer **142** are a plurality of through holes **163**T**12** constituting respective portions of the plurality of through hole lines **163**T. All the through holes represented by circles in FIG. **22**, except the through holes **107**T**12** and **108**T**12**, are the through holes **163**T**12**. The plurality of through holes **163**T**11** shown in FIG. **21** are connected to the plurality of through holes **163**T**12**, respectively.

FIG. **23** illustrates a patterned surface of each of the thirteenth to twenty-first dielectric layers **143** to **151**. Seven through holes **107**T**13** constituting respective portions of the seven through hole lines **107**T are formed in each of the dielectric layers **143** to **151**. The seven through holes **107**T**12** shown in FIG. **22** are respectively connected to the seven through holes **107**T**13** formed in the thirteenth dielectric layer **143**.

In each of the dielectric layers **143** to **151**, there are further formed two through holes **108**T**13** constituting respective portions of the two through hole lines **108**T. The two through holes **108**T**12** shown in FIG. **22** are respectively connected to the two through holes **108**T**13** formed in the thirteenth dielectric layer **143**.

Further, a plurality of through holes **163**T**13** constituting respective portions of the plurality of through hole lines **163**T are formed in each of the dielectric layers **143** to **151**. All the through holes represented by circles in FIG. **23**, except the through holes **107**T**13** and **108**T**13**, are the through holes **163**T**13**. The plurality of through holes **163**T**12** shown in FIG. **22** are respectively connected to the plurality of through holes **163**T**13** formed in the thirteenth dielectric layer **143**.

In the dielectric layers **143** to **151**, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. **24** illustrates a patterned surface of the twenty-second dielectric layer **152**. The second conductor layer **1521** forming the second portion **62** of the shield **6** is formed on the patterned surface of the dielectric layer **152**. The through holes **107**T**13**, **108**T**13** and **163**T**13** formed in the twenty-first dielectric layer **151** are connected to the second conductor layer **1521**.

The band-pass filter **100** according to the present embodiment is formed by stacking the first to twenty-second dielectric layers **131** to **152** such that the patterned surface of the first dielectric layer **131** also serves as the first end face **2**A of the main body **2**. A surface of the twenty-second dielectric layer **152** opposite to the patterned surface serves as the second end face **2**B of the main body **2**. The first to twenty-second dielectric layers **131** to **152** constitute the multilayer stack **20**.

The respective resonator conductor portions **1510**, **1520**, **1530**, **1540**, **1550** and **1560** of the resonators **151** to **156** are located at the same position in the multilayer stack **20** in the first direction, i.e., the Z direction.

The conductor layer **1311** forming the first input/output port **3** is connected to the conductor layer **1401** shown in FIG. **20** via the through holes **131**T**1**, **132**T**1**, **134**T**1** and **135**T**1**. The conductor layer **1401** is opposed to a portion of the resonator conductor portion **1510** (FIG. **22**) near the first end **1510***a* with the dielectric layers **140** and **141** interposed therebetween. The capacitor C**101** shown in FIG. **15** is composed of the conductor layer **1401** and the resonator conductor portion **1510**, and also the dielectric layers **140** and **141** interposed therebetween.

The conductor layer **1312** forming the second input/output port **4** is connected to the conductor layer **1402** shown in FIG. **20** via the through holes **131**T**2**, **132**T**2**, **134**T**2** and **135**T**2**. The conductor layer **1402** is opposed to a portion of the resonator conductor portion **1560** (FIG. **22**) near the first end **1560***a* with the dielectric layers **140** and **141** interposed therebetween. The capacitor C**102** shown in FIG. **15** is composed of the conductor layer **1402** and the resonator conductor portion **1560**, and also the dielectric layers **140** and **141** interposed therebetween.

The conductor layer **1403** shown in FIG. **20** is opposed to a portion of the resonator conductor portion **1510** near the second end **1510***b* and to a portion of the resonator conductor portion **1520** near the first end **1520***a*, with the dielectric layers **140** and **141** interposed between the conductor layer **1403** and each of the aforementioned respective portions of the resonator conductor portions **1510** and **1520**. The capacitor C**112** shown in FIG. **15** is composed of the conductor layer **1403**, the resonator conductor portions **1510** and **1520**, and the dielectric layers **140** and **141** interposed between the conductor layer **1403** and the resonator conductor portions **1510** and **1520**.

The conductor layer **1404** shown in FIG. **20** is opposed to a portion of the resonator conductor portion **1520** near the second end **1520***b* and to a portion of the resonator conductor portion **1530** near the first end **1530***a*, with the dielectric layers **140** and **141** interposed between the conductor layer **1404** and each of the aforementioned respective portions of the resonator conductor portions **1520** and **1530**. The capacitor C**123** shown in FIG. **15** is composed of the conductor layer **1404**, the resonator conductor portions **1520** and **1530**, and the dielectric layers **140** and **141** interposed between the conductor layer **1404** and the resonator conductor portions **1520** and **1530**.

The conductor layer **1405** shown in FIG. **20** is opposed to a portion of the resonator conductor portion **1530** near the first end **1530***a* and to a portion of the resonator conductor portion **1540** near the first end **1540***a*, with the dielectric layers **140** and **141** interposed between the conductor layer **1405** and each of the aforementioned respective portions of the resonator conductor portions **1530** and **1540**. The capacitor C**134** shown in FIG. **15** is composed of the conductor layer **1405**, the resonator conductor portions **1530** and **1540**, and the dielectric layers **140** and **141** interposed between the conductor layer **1405** and the resonator conductor portions **1530** and **1540**.

The conductor layer **1406** shown in FIG. **20** is opposed to a portion of the resonator conductor portion **1540** near the first end **1540***a* and to a portion of the resonator conductor portion **1550** near the second end **1550***b*, with the dielectric layers **140** and **141** interposed between the conductor layer **1406** and each of the aforementioned respective portions of the resonator conductor portions **1540** and **1550**. The capacitor C**145** shown in FIG. **15** is composed of the conductor layer **1406**, the resonator conductor portions **1540** and **1550**, and the dielectric layers **140** and **141** interposed between the conductor layer **1406** and the resonator conductor portions **1540** and **1550**.

The conductor layer **1407** shown in FIG. **20** is opposed to a portion of the resonator conductor portion **1550** near the first end **1550***a* and to a portion of the resonator conductor portion **1560** near the second end **1560***b*, with the dielectric layers **140** and **141** interposed between the conductor layer **1407** and each of the aforementioned respective portions of the resonator conductor portions **1550** and **1560**. The capacitor C**156** shown in FIG. **15** is composed of the conductor layer **1407**, the resonator conductor portions **1550** and **1560**, and the dielectric layers **140** and **141** interposed between the conductor layer **1407** and the resonator conductor portions **1550** and **1560**.

Each of the seven through hole lines **107**T of the partition **107** is formed by connecting the through holes **107**T1, **107**T2, **107**T4, **107**T5, **107**T10, **107**T11, **107**T12 and **107**T13 in series in the Z direction.

In the example shown in FIG. **16** to FIG. **24**, the partition **107** extends to pass between the resonator conductor portion **1520** and the resonator conductor portion **1550**, and is in contact with the first portion **61** and the second portion **62**.

Each of the two through hole lines **108**T of the coupling adjustment section **108** is formed by connecting the through holes **108**T1, **108**T2, **108**T4, **108**T5, **108**T10, **108**T11, **108**T12 and **108**T13 in series in the Z direction.

Each of the plurality of through hole lines **163**T of the connecting portion **163** is formed by connecting the through holes **163**T1, **163**T2, **163**T4, **163**T5, **163**T10, **163**T11, **163**T12 and **163**T13 in series in the Z direction.

In the present embodiment, the resonators **152** and **155** which are not adjacent to each other in circuit configuration are magnetically coupled to each other, while the resonators **151** and **156** which are not adjacent to each other in circuit configuration are capacitively coupled to each other. The resonator **152** and the resonator **151** are adjacent to each other in circuit configuration and are also capacitively coupled to each other. The resonator **155** and the resonator **156** are adjacent to each other in circuit configuration and are also capacitively coupled to each other. The resonator conductor portions **1510**, **1520**, **1550** and **1560** of the resonators **151**, **152**, **155** and **156** having such relationships in circuit configuration have the following physical relationships with each other.

The resonator conductor portion **1520** of the resonator **152** and the resonator conductor portion **1550** of the resonator **155** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. In the present embodiment, in particular, the resonator conductor portion **1520** and the resonator conductor portion **1550**, both of which extend in the Y direction, are physically adjacent to each other in the X direction without any resonator conductor portion of another resonator therebetween. The magnetic coupling between the resonators **152** and **155** is thereby achieved.

The resonator conductor portion **1510** of the resonator **151** and the resonator conductor portion **1560** of the resonator **156** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. In the present embodiment, in particular, the second end **1510***b* of the resonator conductor portion **1510** and the second end **1560***b* of the resonator conductor portion **1560** are at a small distance from each other and adjacent to each other, without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **151** and **156** is thereby achieved.

The resonator conductor portion **1520** of the resonator **152** and the resonator conductor portion **1510** of the resonator **151** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **152** and **151** is thereby achieved easily.

The resonator conductor portion **1550** of the resonator **155** and the resonator conductor portion **1560** of the resonator **156** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **155** and **156** is thereby achieved easily.

The function and effects of the band-pass filter **100** according to the present embodiment will now be described. For example, the band-pass filter **100** is designed and configured to have a passband in a quasi-millimeter wave band of 10 to 30 GHz or a millimeter wave band of 30 to 300 GHz.

In the present embodiment, the partition **107** divides the space defined by the shield **6** into a space in which the resonator conductor portion **1520** is located and a space in which the resonator conductor portion **1550** is located. The present embodiment thus prevents the attenuation characteristic in the frequency region above the passband from being degraded by the lowest-order waveguide mode, like the first embodiment.

Further, in the present embodiment, the second stage resonator **152** and the fifth stage resonator **155**, which are not adjacent to each other in circuit configuration, are magnetically coupled to each other. The magnetic coupling between the resonators **152** and **155** enables creation of attenuation poles in both of the first and second passband-vicinity regions in the frequency response of the insertion loss, the first passband-vicinity region being close to the passband and lower than the passband, the second passband-vicinity region being close to the passband and higher than the passband.

In the present embodiment, the first stage resonator **151** and the sixth stage resonator **156**, which are not adjacent to each other in circuit configuration, are capacitively coupled to each other. The capacitive coupling between the resonators **151** and **156** has the effect of increasing the insertion loss at the attenuation pole occurring in the first passband-vicinity region. The magnitude of the insertion loss at the attenuation pole occurring in the first passband-vicinity region is adjustable by adjusting the magnitude of the capacitive coupling between the resonators **151** and **156**. The coupling adjustment section **108** is provided to adjust the magnitude of the capacitive coupling between the resonators **151** and **156**. In other words, the magnitude of the capacitive coupling between the resonators **151** and **156** is adjustable by adjusting the number of and distance between the plurality of through hole lines **108**T constituting the coupling adjustment section **108**.

The present embodiment achieves such a characteristic that the insertion loss steeply changes in both of the first passband-vicinity region and the second passband-vicinity region, and in particular, achieves such a characteristic that the insertion loss changes more steeply in the first passband-vicinity region than in the second passband-vicinity region.

In the present embodiment, the partition **107** is disposed to pass between the resonator conductor portion **1520** and the resonator conductor portion **1550**. The resonator conductor portion **1520** and the resonator conductor portion **1550** respectively constitute the resonator **152** and the resonator **155**, which are magnetically coupled to each other although not adjacent to each other in circuit configuration. The magnetic coupling between the resonators **152** and **155** can be weaker than the electromagnetic coupling between any two resonators that are adjacent to each other in circuit configuration. According to the present embodiment, it is thus possible to establish magnetic coupling between the resonators **152** and **155** while disposing the partition **107** to pass between the resonator conductor portion **1520** and the resonator conductor portion **1550**. The present embodiment thus achieves both of prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode by the provision of the partition **107** and the creation of attenuation poles by establishing magnetic coupling between the resonators **152** and **155**. This results in the favorable characteristics of the band-pass filter **100**.

In the present embodiment, the resonator conductor portions **1510**, **1520**, **1550** and **1560** of the resonators **151**, **152**, **155** and **156** having the above-described relationship in circuit configuration are configured to have the above-described physical relationship. The present embodiment thus realizes the band-pass filter **100** which has two cross couplings and is simple in structure.

Now, an example of characteristics of the band-pass filter **100** according to the present embodiment and an example of characteristics of a band-pass filter of a second comparative example will be discussed. The band-pass filter of the second comparative example has the same configuration as that of the band-pass filter **100** except that the partition **107** is omitted.

FIG. **25** illustrates an example frequency response of the insertion loss of the band-pass filter **100** according to the present embodiment. FIG. **26** illustrates an example frequency response of the insertion loss of the band-pass filter of the second comparative example. The frequency responses shown in FIGS. **25** and **26** were obtained by simulation. In FIGS. **25** and **26**, the horizontal axis represents frequency, and the vertical axis represents insertion loss. In the examples shown in FIGS. **25** and **26**, the band-pass filter **100** and the band-pass filter of the second comparative example have a passband of approximately 26 to 30 GHz, and the center frequency of the passband is approximately 28 GHz.

For the band-pass filter **100** used in the simulation, the magnitudes of the two cross couplings were adjusted, based on the presence of the partition **107**, so as to obtain such a characteristic that the insertion loss steeply changes in both of the first passband-vicinity region and the second passband-vicinity region, as shown in FIG. **25**. The first passband-vicinity region is a frequency region of approximately 24 to 26 GHz. The second passband-vicinity region is a frequency region of approximately 30 to 32 GHz. Note that the characteristic shown in FIG. **25** exhibits no apparent attenuation pole in the second passband-vicinity region. This is because the capacitive coupling between the resonators **151** and **156** caused a slight reduction in the insertion loss at an attenuation pole that was caused to occur in the second passband-vicinity region by the magnetic coupling between the resonators **152** and **155**. Although no apparent attenuation pole is observed in the second passband-vicinity region, the characteristic shown in FIG. **25** exhibits a steep change in the insertion loss in that region.

The characteristic of the band-pass filter of the second comparative example shown in FIG. **26** exhibits a lower insertion loss than that of the band-pass filter **100** in both of the first passband-vicinity region and the second passband-vicinity region. This is because, for the band-pass filter of the second comparative example, the omission of the partition **107** resulted in a deviation of the magnitude of the magnetic coupling between the resonators **152** and **155** from the adjusted magnitude in the band-pass filter **100**.

Further, the characteristic of the band-pass filter of the second comparative example shown in FIG. **26** exhibits a peak of an extreme reduction in the insertion loss in a frequency region near 50 GHz. This is considered to be due to unwanted resonance caused by the lowest-order waveguide mode. In the characteristic of the band-pass filter **100** shown in FIG. **25**, when compared with the characteristic shown in FIG. **26**, the peak present in the frequency region near 50 GHz is shifted to a higher frequency and the insertion loss at this peak is higher. Accordingly, the characteristic shown in FIG. **25** is better than the characteristic shown in FIG. **26** in terms of attenuation characteristic in a frequency region above the passband.

It is apparent from FIG. **25** that the band-pass filter **100** according to the present embodiment provides the favorable characteristics achieving steep changes in the insertion loss in both of the first and second passband-vicinity regions and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

The configuration, operation and effects of the present embodiment are otherwise the same as those of the first embodiment.

Third Embodiment

A third embodiment of the present invention will now be described with reference to FIG. **27** and FIG. **28**. FIG. **27** is a perspective view illustrating the structure of a band-pass filter according to the third embodiment. FIG. **28** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the third embodiment.

The band-pass filter **200** according to the present embodiment includes the main body **2**, the first input/output port **3**, the second input/output port **4**, three or more resonators, the shield **6**, and a partition **207**. The main body **2** includes the multilayer stack **20**.

The three or more resonators are located between the first input/output port **3** and the second input/output port **4** in circuit configuration. In the present embodiment, the three or more resonators are three resonators **251**, **252** and **253**. The three resonators **251**, **252** and **253** are arranged in this order, from closest to farthest, from the first input/output port **3** in circuit configuration. The three resonators **251** to **253** are configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. Specifically, the resonators **251** to **253** are configured so that the resonators **251** and **252** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, and the resonators **252** and **253** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other. In the present embodiment, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is specifically capacitive coupling. In the present embodiment, each of the resonators **251** to **253** is a resonator with open ends, and also a half-wave resonator.

The first portion **61**, the second portion **62** and the connecting portion **63** of the shield **6** are arranged to surround the three resonators **251** to **253**. The first portion **61** is formed of a first conductor layer **610** disposed on the first end face **21***a* of the main portion **21** of the multilayer stack **20**. The second portion **62** is formed of a second conductor layer **620** disposed on the second end face **21***b* of the main portion **21** of the multilayer stack **20**.

The band-pass filter **200** includes a capacitor C**212** for establishing capacitive coupling between the resonators **251** and **252**, and a capacitor C**223** for establishing capacitive coupling between the resonators **252** and **253**.

In the present embodiment, among the three resonators **251** to **253**, the resonator **251**, which is the closest to the first input/output port **3** in circuit configuration, and the resonator **253**, which is the closest to the second input/output port **4** in circuit configuration, are magnetically coupled to each other although they are not adjacent to each other in circuit configuration. The resonator **251** corresponds to the first resonator in the present invention. The resonator **253** corresponds to the second resonator in the present invention.

The band-pass filter **200** further includes a capacitor C**201** provided between the first input/output port **3** and the resonator **251**, and a capacitor C**202** provided between the second input/output port **4** and the resonator **253**.

The band-pass filter **200** further includes the two lines **91** and **92** as in the first embodiment.

The resonator **251** includes a resonator conductor portion **2510** formed of a conductor. The resonator **252** includes a resonator conductor portion **2520** formed of a conductor. The resonator **253** includes a resonator conductor portion **2530** formed of a conductor. The resonator conductor portion **2510** corresponds to the first resonator conductor portion in the present invention. The resonator conductor portion **2530** corresponds to the second resonator conductor portion in the present invention.

The resonator conductor portions **2510**, **2520** and **2530** are located at the same position in the multilayer stack **20** in the first direction, i.e., the Z direction. Each of the resonator conductor portions **2510**, **2520** and **2530** extends in a direction intersecting the first direction or the Z direction. In the present embodiment, specifically, each of the resonator conductor portions **2510**, **2520** and **2530** extends in a direction orthogonal to the first direction or the Z direction.

Each of the resonator conductor portions **2510**, **2520** and **2530** has a first end and a second end opposite to each other. As mentioned above, each of the resonators **251** to **253** is a resonator with open ends. Thus, both of the first and second ends of each of the resonator conductor portions **2510**, **2520** and **2530** are open. Each of the resonator conductor portions **2510**, **2520** and **2530** has a length of one half or nearly one half the wavelength corresponding to the center frequency of the passband of the band-pass filter **200**.

The partition **207** is in contact with the first portion **61** and the second portion **62**. At least part of the partition **207** extends to pass between the resonator conductor portion **2510** and the resonator conductor portion **2530**. In the present embodiment, specifically, the partition **207** extends in the first direction, i.e., the Z direction. The partition **207** connects the first portion **61** and the second portion **62** via the shortest path. To be more specific, the length of the partition **207** in the Z direction is equal to the distance between the first portion **61** and the second portion **62**.

The partition **207** runs through the two or more dielectric layers constituting the main portion **21**. In the present embodiment, the partition **207** includes a plurality of through hole lines **207**T each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **207**T correspond to the plurality of first through hole lines in the present invention. In FIG. **27**, each through hole line **207**T is represented by a circular column. Each of the through hole lines **207**T includes two or more through holes connected in series. Each of the through hole lines **207**T extends in the Z direction.

In the present embodiment, the resonator conductor portion **2510** and the resonator conductor portion **2530** extend in the Y direction and are adjacent to each other in the X direction with a predetermined spacing therebetween. The through hole lines **207**T are arranged to be adjacent to each other in the Y direction and pass between the resonator conductor portions **2510** and **2530**. In the present embodiment, the number of the through hole lines **207**T is six.

The connecting portion **63** of the shield **6** includes a plurality of through hole lines **263**T each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **263**T correspond to the second through hole lines in the present invention. In FIG. **27**, each through hole line **263**T is represented by a circular column. All the through hole lines represented by circular columns in FIG. **27**, except the six through hole lines **207**T, are the through hole lines **263**T. Each of the through hole lines **263**T includes two or more through holes connected in series. Each of the through hole lines **263**T extends in the Z direction.

The band-pass filter **200** further includes conductor layers **211**, **212**, **221** and **222** provided inside the multilayer stack **20**.

The conductor layer **211** has a first end and a second end opposite to each other. A portion of the conductor layer **211** near the first end thereof is connected to the first input/output port **3** via a plurality of through holes provided in the multilayer stack **20**. A portion of the conductor layer **211** near the second end thereof is opposed to a portion of the resonator conductor portion **2510** near the first end thereof with one or more dielectric layers interposed therebetween. The capacitor C**201** is thereby formed. The line **91** is connected to the first input/output port **3** via one or more of the through holes connecting the conductor layer **211** and the first input/output port **3**.

The conductor layer **212** has a first end and a second end opposite to each other. A portion of the conductor layer **212** near the first end thereof is connected to the second input/output port **4** via a plurality of through holes provided in the multilayer stack **20**. A portion of the conductor layer **212** near the second end thereof is opposed to a portion of the resonator conductor portion **2530** near the first end thereof with one or more dielectric layers interposed therebetween. The capacitor C**202** is thereby formed. The line **92** is connected to the second input/output port **4** via one or more of the through holes connecting the conductor layer **212** and the second input/output port **4**.

The conductor layer **221** is opposed to a portion of the resonator conductor portion **2510** near the second end thereof and to a portion of the resonator conductor portion **2520** near the first end thereof with one or more dielectric layers interposed between the conductor layer **221** and each of the aforementioned respective portions of the resonator conductor portions **2510** and **2520**. The capacitor C**212** is thereby formed.

The conductor layer **222** is opposed to a portion of the resonator conductor portion **2520** near the second end thereof and to a portion of the resonator conductor portion **2530** near the second end thereof with one or more dielectric layers interposed between the conductor layer **222** and each of the aforementioned respective portions of the resonator conductor portions **2520** and **2530**. The capacitor C**223** is thereby formed.

In the present embodiment, the partition **207** divides the space defined by the shield **6** into a space in which the resonator conductor portion **2510** is located and a space in which the resonator conductor portion **2530** is located. The present embodiment thus prevents the attenuation characteristic in the frequency region above the passband from being degraded by the lowest-order waveguide mode, like the first embodiment.

Further, in the present embodiment, the first stage resonator **251** and the third stage resonator **253**, which are not adjacent to each other in circuit configuration, are magnetically coupled to each other. The magnetic coupling between the resonators **251** and **253** enables creation of an attenuation pole in the first passband-vicinity region, which is a frequency region close to the passband and lower than the passband, in the frequency response of the insertion loss.

By virtue of the above features, the band-pass filter **200** according to the present embodiment provides the favorable characteristics achieving steep changes in the insertion loss in the first passband-vicinity region and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

The configuration, operation and effects of the present embodiment are otherwise the same as those of the first embodiment.

Fourth Embodiment

A fourth embodiment of the present invention will now be described with reference to FIG. **29** and FIG. **30**. FIG. **29** is a perspective view illustrating the structure of a band-pass filter according to the fourth embodiment. FIG. **30** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the fourth embodiment.

The band-pass filter **300** according to the present embodiment includes the main body **2**, the first input/output port **3**, the second input/output port **4**, three or more resonators, the shield **6**, and a partition **307**. The main body **2** includes the multilayer stack **20**.

The three or more resonators are located between the first input/output port **3** and the second input/output port **4** in circuit configuration. In the present embodiment, the three or more resonators are four resonators **351**, **352**, **353** and **354**. The four resonators **351**, **352**, **353** and **354** are arranged in this order, from closest to farthest, from the first input/output port **3** in circuit configuration. The four resonators **351** to **354** are configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. Specifically, the resonators **351** to **354** are configured so that the resonators **351** and **352** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators **352** and **353** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, and the resonators **353** and **354** are adjacent to each other in circuit configuration and are electromagnetically coupled to each other. In the present embodiment, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is specifically capacitive coupling. In the present embodiment, each of the resonators **351** to **354** is a resonator with open ends, and also a half-wave resonator.

The first portion **61**, the second portion **62** and the connecting portion **63** of the shield **6** are arranged to surround the four resonators **351** to **354**. The first portion **61** is formed of the first conductor layer **610** disposed on the first end face **21***a* of the main portion **21** of the multilayer stack **20**. The second portion **62** is formed of the second conductor layer **620** disposed on the second end face **21***b* of the main portion **21** of the multilayer stack **20**.

The band-pass filter **300** includes a capacitor C**312** for establishing capacitive coupling between the resonators **351** and **352**, a capacitor C**323** for establishing capacitive coupling between the resonators **352** and **353**, and a capacitor C**334** for establishing capacitive coupling between the resonators **353** and **354**.

In the present embodiment, among the four resonators **351** to **354**, the resonator **351**, which is the closest to the first input/output port **3** in circuit configuration, and the resonator **354**, which is the closest to the second input/output port **4** in circuit configuration, are magnetically coupled to each other although they are not adjacent to each other in circuit configuration. The resonator **351** corresponds to the first resonator in the present invention. The resonator **354** corresponds to the second resonator in the present invention.

The band-pass filter **300** further includes a capacitor C**301** provided between the first input/output port **3** and the resonator **351**, and a capacitor C**302** provided between the second input/output port **4** and the resonator **354**.

The band-pass filter **300** further includes the two lines **91** and **92** as in the first embodiment.

The resonator **351** includes a resonator conductor portion **3510** formed of a conductor. The resonator **352** includes a resonator conductor portion **3520** formed of a conductor. The resonator **353** includes a resonator conductor portion **3530** formed of a conductor. The resonator **354** includes a resonator conductor portion **3540** formed of a conductor. The resonator conductor portion **3510** corresponds to the first resonator conductor portion in the present invention. The resonator conductor portion **3540** corresponds to the second resonator conductor portion in the present invention.

The resonator conductor portions **3510**, **3520**, **3530** and **3540** are located at the same position in the multilayer stack **20** in the first direction, i.e., the Z direction. Each of the resonator conductor portions **3510**, **3520**, **3530** and **3540** extends in a direction intersecting the first direction or the Z direction. In the present embodiment, specifically, each of the resonator conductor portions **3510**, **3520**, **3530** and **3540** extends in a direction orthogonal to the first direction or the Z direction.

Each of the resonator conductor portions **3510**, **3520**, **3530** and **3540** has a first end and a second end opposite to each other. As mentioned above, each of the resonators **351** to **354** is a resonator with open ends. Thus, both of the first and second ends of each of the resonator conductor portions **3510**, **3520**, **3530** and **3540** are open. Each of the resonator conductor portions **3510**, **3520**, **3530** and **3540** has a length of one half or nearly one half the wavelength corresponding to the center frequency of the passband of the band-pass filter **300**.

The partition **307** is in contact with the first portion **61** and the second portion **62**. At least part of the partition **307** extends to pass between the resonator conductor portion **3510** and the resonator conductor portion **3540**. In the present embodiment, specifically, the partition **307** extends in the first direction, i.e., the Z direction. The partition **307** connects the first portion **61** and the second portion **62** via the shortest path. To be more specific, the length of the partition **307** in the Z direction is equal to the distance between the first portion **61** and the second portion **62**.

The partition **307** runs through the two or more dielectric layers constituting the main portion **21**. In the present embodiment, the partition **307** includes a plurality of through hole lines **307**T each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **307**T correspond to the plurality of first through hole lines in the present invention. In FIG. **29**, each through hole line **307**T is represented by a circular column. Each of the through hole lines **307**T includes two or more through holes connected in series. Each of the through hole lines **307**T extends in the Z direction.

In the present embodiment, the resonator conductor portion **3510** and the resonator conductor portion **3540** extend in the Y direction and are adjacent to each other in the X direction with a predetermined spacing therebetween. The through hole lines **307**T are arranged to be adjacent to each other in the Y direction and pass between the resonator conductor portions **3510** and **3540**. In the present embodiment, the number of the through hole lines **307**T is six.

The connecting portion **63** of the shield **6** includes a plurality of through hole lines **363**T each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **363**T correspond to the second through hole lines in the present invention. In FIG. **29**, each through hole line **363**T is represented by a circular column. All the through hole lines represented by circular columns in FIG. **29**, except the six through hole lines **307**T, are the through hole lines **363**T. Each of the through hole lines **363**T includes two or more through holes connected in series. Each of the through hole lines **363**T extends in the Z direction.

The band-pass filter **300** further includes conductor layers **311**, **312**, **321**, **322** and **323** provided inside the multilayer stack **20**.

The conductor layer **311** has a first end and a second end opposite to each other. A portion of the conductor layer **311** near the first end thereof is connected to the first input/output port **3** via a plurality of through holes provided in the multilayer stack **20**. A portion of the conductor layer **311** near the second end thereof is opposed to a portion of the resonator conductor portion **3510** near the first end thereof with one or more dielectric layers interposed therebetween. The capacitor C**301** is thereby formed. The line **91** is connected to the first input/output port **3** via one or more of the through holes connecting the conductor layer **311** and the first input/output port **3**.

The conductor layer **312** has a first end and a second end opposite to each other. A portion of the conductor layer **312** near the first end thereof is connected to the second input/output port **4** via a plurality of through holes provided in the multilayer stack **20**. A portion of the conductor layer **312** near the second end thereof is opposed to a portion of the resonator conductor portion **3540** near the first end thereof with one or more dielectric layers interposed therebetween. The capacitor C**302** is thereby formed. The line **92** is connected to the second input/output port **4** via one or more of the through holes connecting the conductor layer **312** and the second input/output port **4**.

The conductor layer **321** is opposed to a portion of the resonator conductor portion **3510** near the second end thereof and to a portion of the resonator conductor portion **3520** near the first end thereof with one or more dielectric layers interposed between the conductor layer **321** and each of the aforementioned respective portions of the resonator conductor portions **3510** and **3520**. The capacitor C**312** is thereby formed.

The conductor layer **322** is opposed to a portion of the resonator conductor portion **3520** near the first end thereof and to a portion of the resonator conductor portion **3530** near the first end thereof with one or more dielectric layers interposed between the conductor layer **322** and each of the aforementioned respective portions of the resonator conductor portions **3520** and **3530**. The capacitor C**323** is thereby formed.

The conductor layer **323** is opposed to a portion of the resonator conductor portion **3530** near the first end thereof and to a portion of the resonator conductor portion **3540** near the second end thereof with one or more dielectric layers interposed between the conductor layer **323** and each of the aforementioned respective portions of the resonator conductor portions **3530** and **3540**. The capacitor C**334** is thereby formed.

In the present embodiment, the partition **307** divides the space defined by the shield **6** into a space in which the resonator conductor portion **3510** is located and a space in which the resonator conductor portion **3540** is located. The present embodiment thus prevents the attenuation characteristic in the frequency region above the passband from being degraded by the lowest-order waveguide mode, as does the first embodiment.

In the present embodiment, the first stage resonator **351** and the fourth stage resonator **354**, which are not adjacent to each other in circuit configuration, are magnetically coupled to each other. The magnetic coupling between the resonators **351** and **354** enables creation of attenuation poles in both of the first and second passband-vicinity regions in the frequency response of the insertion loss, the first passband-vicinity region being close to the passband and lower than the passband, the second passband-vicinity region being close to the passband and higher than the passband.

By virtue of the above features, the band-pass filter **300** according to the present embodiment provides the favorable characteristics achieving steep changes in the insertion loss in both of the first and second passband-vicinity regions and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

The configuration, operation and effects of the present embodiment are otherwise the same as those of the first embodiment.

The present invention is not limited to the foregoing embodiments, and various modifications may be made thereto. For example, the number and the configuration of the resonators are not limited to those illustrated in the foregoing embodiments, and can be freely chosen as far as the requirements of the appended claims are met. Further, at least part of the connecting portion of the shield **6** may be composed of conductor layer(s) formed on one or more side surfaces of the main body **2**, instead of a plurality of through hole lines. Still further, the partition may be composed of plate-shaped conductor portions, instead of a plurality of through hole lines.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. Thus, it is to be understood that, within the scope of the appended claims and equivalents thereof, the invention may be practiced in other embodiments than the foregoing most preferable embodiments.

What is claimed is:

1. A band-pass filter comprising:

a main body formed of a dielectric;

a first input/output port and a second input/output port integrated with the main body;

three or more resonators provided within the main body, located between the first input/output port and the second input/output port in circuit configuration, and configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration;

a shield formed of a conductor and integrated with the main body; and

a partition formed of a conductor, provided within the main body, and electrically connected to the shield, wherein:

the shield includes a first portion and a second portion spaced from each other in a first direction, and a connecting portion connecting the first and second portions,

the first portion, the second portion and the connecting portion are arranged to surround the three or more resonators,

the three or more resonators include a first resonator and a second resonator that are configured to be magnetically coupled to each other although not adjacent to each other in circuit configuration,

the first resonator includes a first resonator conductor portion formed of a conductor,

the second resonator includes a second resonator conductor portion formed of a conductor,

each of the first and second resonator conductor portions extends in a direction intersecting the first direction,

the partition is in contact with the first portion and the second portion,

at least part of the partition extends to pass between the first resonator conductor portion and the second resonator conductor portion, and

each of the three or more resonators is a resonator with open ends.

2. The band-pass filter according to claim **1**, wherein the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is capacitive coupling.

3. The band-pass filter according to claim **1**, further comprising a notch filter section for attenuating a signal of a predetermined frequency higher than a passband of the band-pass filter.

4. The band-pass filter according to claim **1**, wherein the partition extends in the first direction and connects the first portion and the second portion via a shortest path.

5. The band-pass filter according to claim **1**, wherein

the first resonator is a resonator that is the closest to the first input/output port in circuit configuration, and

the second resonator is a resonator that is the closest to the second input/output port in circuit configuration.

6. The band-pass filter according to claim **5**, wherein the three or more resonators are five resonators.

7. The band-pass filter according to claim **1**, wherein

the first resonator is a resonator that is the second closest to the first input/output port in circuit configuration, and

the second resonator is a resonator that is the second closest to the second input/output port in circuit configuration.

8. The band-pass filter according to claim **7**, wherein the three or more resonators are six resonators.

9. A band-pass filter comprising:

a main body formed of a dielectric;

a first input/output port and a second input/output port integrated with the main body;

three or more resonators provided within the main body, located between the first input/output port and the second input/output port in circuit configuration, and configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration;

a shield formed of a conductor and integrated with the main body; and

a partition formed of a conductor, provided within the main body, and electrically connected to the shield, wherein:

the shield includes a first portion and a second portion spaced from each other in a first direction, and a connecting portion connecting the first and second portions,

the first portion, the second portion and the connecting portion are arranged to surround the three or more resonators,

the three or more resonators include a first resonator and a second resonator that are configured to be magnetically coupled to each other although not adjacent to each other in circuit configuration,

the first resonator includes a first resonator conductor portion formed of a conductor,

the second resonator includes a second resonator conductor portion formed of a conductor,

each of the first and second resonator conductor portions extends in a direction intersecting the first direction,

at least part of the partition extends to pass between the first resonator conductor portion and the second resonator conductor portion,

the main body includes a multilayer stack composed of a plurality of dielectric layers stacked together in the first direction,

the first resonator conductor portion and the second resonator conductor portion are located at the same position in the multilayer stack in the first direction, and

the partition extends through two or more dielectric layers stacked together, among the plurality of dielectric layers, and is in contact with the first portion and the second portion.

10. The band-pass filter according to claim **9**, further comprising a notch filter section for attenuating a signal of a predetermined frequency higher than a passband of the band-pass filter.

11. The band-pass filter according to claim **9**, wherein

the multilayer stack includes a main portion composed of the two or more dielectric layers,

the main portion has a first end face and a second end face located at opposite ends in the first direction,

the first portion is formed of a first conductor layer disposed on the first end face, and

the second portion is formed of a second conductor layer disposed on the second end face.

12. The band-pass filter according to claim **11**, wherein
the partition includes a plurality of first through hole lines each running through the two or more dielectric layers, and
each of the plurality of first through hole lines includes two or more through holes connected in series.

13. The band-pass filter according to claim **11**, wherein
the connecting portion of the shield includes a plurality of second through hole lines each running through the two or more dielectric layers, and
each of the plurality of second through hole lines includes two or more through holes connected in series.

14. The band-pass filter according to claim **9**, wherein
the first resonator is a resonator that is the second closest to the first input/output port in circuit configuration, and
the second resonator is a resonator that is the second closest to the second input/output port in circuit configuration.

15. The band-pass filter according to claim **14**, wherein the three or more resonators are six resonators.

16. The band-pass filter according to claim **9**, wherein each of the three or more resonators is a resonator with open ends.

17. The band-pass filter according to claim **9**, wherein the partition extends in the first direction and connects the first portion and the second portion via a shortest path.

18. The band-pass filter according to claim **9**, wherein
the first resonator is a resonator that is the closest to the first input/output port in circuit configuration, and
the second resonator is a resonator that is the closest to the second input/output port in circuit configuration.

19. The band-pass filter according to claim **18**, wherein the three or more resonators are five resonators.

20. The band-pass filter according to claim **9**, wherein the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is capacitive coupling.

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